ANNALS
of the Association of American Geographers

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WALTER M. KOLLMORGEN
Editor

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ANNALS of the
Association of American Geographers

Volume 47 MARCH, 1957 Number 1

HISTORICAL GEOGRAPHY OF THE IRON AND STEEL INDUSTRY OF FRANCE

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THE iron industry was widely scattered over 18th century France, as it was over most of the countries of Europe. There were few regions that could not provide its raw materials: charcoal and iron ore. Whatever the method employed to smelt the ore, the equipment was relatively cheap to build and simple to operate. Furthermore, the finished articles were in universal demand, but their weight and the difficulties inherent in their transport at this time made it imperative that the local market should be supplied from local furnaces and forges.

Methods of smelting and refining iron belonged to two main types. The older was the so-called direct method. The ore was reduced to metallic iron on a forge or "Catalan" hearth. Charcoal fuel was used, and though the fire was always blown by bellows of one kind or another, the temperature was rarely high enough for complete fusion of the metal. Instead it was reduced to a pasty mass, through which were distributed particles of slag. On the other hand, the metal at this temperature absorbed very little carbon, and the small scale of the operation permitted the iron-master so to manipulate both the "bloom" of iron and the stream of air from the bellows that such carbon as was absorbed could be oxidized and eliminated. In this way a metal relatively free of carbon and of most other harmful impurities, though containing a good deal of slag, was produced.

The second, or indirect method, produced a similar "soft" iron, but in two separate stages. First the ore was smelted in a blast or "tall" furnace (*haut fourneau, Hochofen*). Much higher temperatures were realized than on the hearth, but control of the process was less fine. A fluid iron, with a high carbon content, was tapped from the furnace. Though it could be run into moulds and be used to make castings, a further refining process was necessary before soft or malleable iron could be obtained. This second process consisted fundamentally in the oxidation and removal of the carbon, and generally it was accomplished on a hearth.

The effect of the blast furnace was to increase the scale of production. Despite the additional labor, the indirect process gave economies in production, and gradually it replaced the direct process. The latter, however, did not finally disappear from France until early in the present century.[1]

The indirect method necessitated a much larger capital investment than the direct. Once constructed, a blast furnace might be expected to remain in use for several decades. Much greater thought was given to the question of location, and the risk of the exhaustion of ore or fuel could not be taken lightly. The replacement of the ancient forge by the combination of blast furnace and refinery tended thus to give greater stability to the geographical pattern of iron-working.

In the 18th century a major factor in the location of the iron industry was the supply of charcoal.[2] Forge-masters were deterred from

[1] André Armengaud, "La Fin des Forges catalanes dans les Pyrénées Ariègeoises," *Annales: Economies-Sociétiés-Civilisations*, Vol. VIII (1953), pp. 62-66.

[2] There is a large literature on this question; see particularly Bertrand Gille, *Les Origines de la Grande Industrie Métallurgique en France* (Paris, n.d.), pp.

building large furnaces by uncertainty in this regard, and public policy was sometimes directed toward the conserving of timber in the interests of other sections of the population. Despite an urgent need for other sources of fuel, attempts to use coke for smelting were made only halfheartedly and without any real success. Nor was the puddling process,[3] patented in England in 1784, used in France to refine the pig iron from the blast furnace until after the Napoleonic Wars.

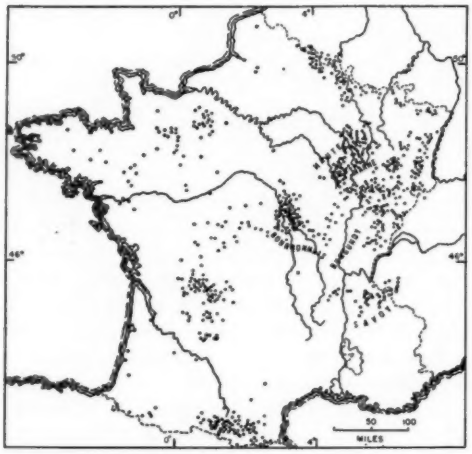

FIG. 1. French iron industry in 1789 (after *H. and G. Bourgin and A. Demangeon*). Boundaries shown are those of 1789. Each dot represents a single ironworks; most represent combined smelting and refining works.

In 1788-9 the Bureau de Commerce conducted a survey of the French iron industry. The returns made to its inquiries allow us to get a picture of the areal distribution of ironworks at this time.[4] Figure 1 shows the distribution of the 600 or more works that were listed. Ironworks at this time were often ephemeral. Their small size allowed them to be abandoned more readily than works involving a greater capital investment. It was unusual for their raw materials to be transported more than a short distance, and it was far more common for an ironworks to shift its location as the source of ore and charcoal in the immediate vicinity became exhausted.

The survey conducted by the Bureau de Commerce showed that few parts of France were without iron-smelting works of some kind. They were, however, absent from Provence, a region climatically unsuited to the production of large quantities of timber, and in the central parts of the Paris Basin, where forests had been replaced by cultivation. Ironworks were most numerous in eastern France, in Burgundy and Lorraine, and on the northern and northwestern margin of the Massif Central. These had the advantages of good local ores and of relatively abundant fuel. The clustered works in the eastern Pyrenees and Savoy used a local ore of an unusually high quality, but their operations were gravely restricted by the shortage of fuel, and many of the works were active only occasionally.

EARLY 19TH CENTURY

The years which followed the fall of Napoleon saw little immediate change in the geographical distribution of the French iron industry. The total number of works was somewhat reduced: in 1826, for example, there were 424 blast furnaces, most of them with refineries, and 106 hearths, or "forges catalanes," which used the direct method of making soft iron.[5] Figure 2 shows how closely their distri-

67-84; Germain Martin, *La Grande Industrie en France sous le Régne de Louis XV* (Paris, 1900), pp. 151-157; Henri Sée, *L'Evolution commerciale et industrielle de la France sous l'Ancien Régime* (Paris, 1925), pp. 290-296. There is a wealth of contemporary literature, especially in the letters and reports of the Intendants; see particularly *Correspondence des Contrôleurs Généraux des Finances avec les Intendants*, edited by A. M. de Boislisle and P. de Brontonne (Paris, 1874-97).

[3] The puddling process consisted in oxidizing and removing carbon and other substances from the iron by "puddling" or kneading it on a closed-in hearth, heated by the incandescent gases from a coal fire. The metal was not allowed to come into contact with the fuel, and thus was prevented from picking up more carbon.

[4] The returns are filed in the Archives Nationales (Paris), F^{12}680; they were edited and published by Hubert and Georges Bourgin, L'Industrie sidérurgique en France au début de la Révolution, *Collection de documents inedits sur l'historie économique de la Révolution française*, Paris, Imprimerie nationale, 1920. A map of the works was compiled and published by A. Demangeon, "La Répartition de l'Industrie du Fer en France en 1789," *Annales de Géographie*, Vol. XXX (1921), pp. 407-415.

[5] A. M. Héron de Villefosse, "Des Métaux en France: Rapport fait au Jury central de l'Exposition des Produits de l'Industrie française . . .," *Annales des Mines*, 2^e série, Vol. II (1827), 401-620.

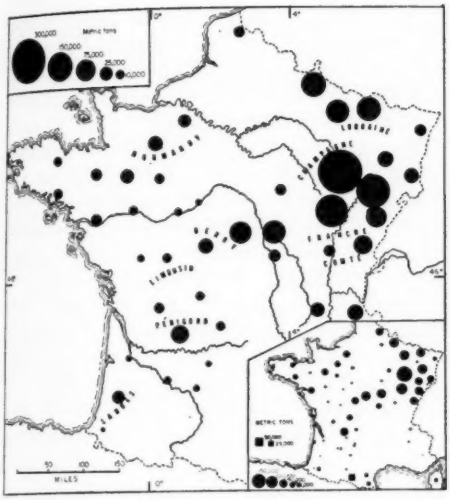

FIG. 2. Production of pig iron, by *départements*, in 1826. The inset shows the production of refined wrought or bar iron. The square symbols represent steel production (after *A. M. Héron de Villefosse*). Boundaries are those of 1815–1860.

bution conformed to that of nearly forty years earlier.

A change in the geographical pattern of the iron and steel industry, and its concentration in a few large centers, each served by a well-developed transportation network, was a consequence primarily of developments in the field of technology. With the exception of the invention of the blast furnace, these developments were of English origin. It is no tribute to the enterprise of French iron-masters that most of these took several decades to cross the Channel from England to France.

In the year 1785 attempts had been made at Le Creusot to smelt with coke.[6] These failed and, despite a considerable interest in the use of mineral fuel, coke-fired blast furnaces were not operated successfully until about 1820. In 1826, less than 2 percent of the pig iron made had been smelted with coke. In 1830, only four blast furnaces out of 379 used coke,[7] but Héron de Villefosse, the most prominent French publicist in this field, had noted that many French iron-masters had displayed a readiness to build furnaces suited to the use of coke fuel.[8]

The ratio of coke-fired to charcoal-fired furnaces steadily increased and by about 1850 half the furnaces used coke. The coke-fired furnaces were also newer and larger than those burning charcoal, so that they contributed nearly two-thirds of the total iron production.[9]

The puddling process, which also used mineral fuel instead of charcoal, first appeared in France in 1821.[10] It was accepted more readily than the use of mineral fuel in the blast furnace, perhaps because the rather difficult preliminary process of making coke was not needed; perhaps also because a faster, cheaper method of refining iron was needed to allow refineries to keep pace with the growing blast furnace output. By 1830, there were 31 works which practiced puddling, with a total of 172 separate furnaces or, as they were called, "forges à l'anglais." They produced at this time 40 percent of the refined or soft iron. The rest was either refined with charcoal or produced directly from the ore on a Catalan forge.

Steel was a rare and expensive commodity. Its chemical nature had been familiar for several decades, but the task of securing just the right percentage of carbon was extremely difficult. In 1826, the steel produced in France amounted to only about 2 percent of the volume of the pig iron. More than half of this was made by the direct method on the Catalan hearth, when the excellence of the steel depended very largely on the skill of the forgemaster in permitting the proper degree of carbon absorption by the metal. The alternative method was the cementation process. By this process refined or soft iron, in the shape of thin bars, was heated in charcoal dust. Some carbon was thus re-absorbed by the bars. By whatever process it was made, the steel was uneven in texture and quality. This irregularity could be removed by the very difficult process of melting down the steel in a sealed crucible. Crucible steel was made in only minute quantities: about 35 tons in 1826.

It is difficult to divide the span of history into periods, each with its characteristic geo-

[6] J. Chevalier, *Le Creusot* (Paris, 1935), pp. 79-94.
[7] A. M. Héron de Villefosse, *Mémoires de l'Académie royale des Sciences de l'Institut de France*, Vol. IX (1830), p. 128.
[8] *Ibid.*, p. 127.
[9] P. Anglés d'Auriac, *L'Evolution de la Sidérurgie française* (St. Étienne, 1913), p. 8.
[10] *Mémoires de l'Académie royale des Sciences, op. cit.*, Vol. IX (1830), p. 161.

graphical pattern of distribution, because in each period there survived some elements of earlier patterns. The pattern of industry until about 1840 may be said to have been dominated by the supply of charcoal and after that date by the availability of coal and coke. But the charcoal blast furnace continued to operate, though of diminishing importance, until the 20th century. A new pattern of distribution, based on the use of coke in the blast furnace and coal on the puddling hearth, emerged slowly. No sooner was it fixed, when further changes in technology began to superimpose another pattern.

THE DOMINANCE OF THE COAL FIELDS

Nevertheless the location of iron works in the years 1840 to 1860 was increasingly dominated by the coal fields, as is suggested by a comparison of Figures 3 and 4. This was a

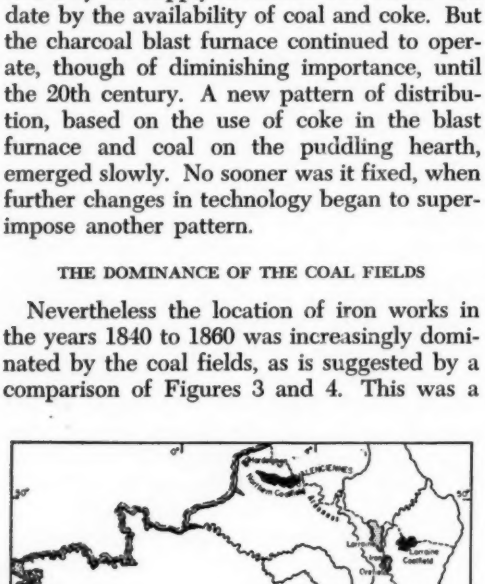

FIG. 3. Coal fields of France (after *Géographie Universelle*, Vol. VI, part ii, p. 659).

period of slowly increasing output both of pig iron and of bar iron. At the end of this period the manufacture of pig or bar iron and of steel was carried on in no less than 1,017 separate establishments, which were scattered over 80 out of the 90 départements of France. There were over 400 blast furnaces; many were so small that the average output of all was only 2,800 metric tons.[11] But about 70 percent of the pig iron was smelted with coke. About half of the pig iron was puddled to make soft iron. The process was extravagant of coal, and was of necessity concentrated on or near the coal fields.

During these years the coal fields which bordered the Massif Central exercised the greatest attraction for the iron industry. The Loire field had long enjoyed the reputation, ill-founded as events were to prove, of being the best endowed of French coal fields. A blackband ore occurred amid the coal measures and certain other ores were to be obtained locally. There had been a small iron industry in and near St. Étienne, providing for a local market. The first blast furnace in this region was built in 1818 and was followed by many others. The production of puddled iron and of cement and crucible steel grew, and by the middle of the century the St. Étienne region was the largest and technically the most advanced of all French centers of the iron and steel industry. It was "le Sheffield français."[12]

Closely related to the works of St. Étienne were those of department Ardèche. Here iron ore occurred close to the right bank of the Rhône, about 50 miles south of St. Étienne. Coal was taken down the river from the eastern extremity of the St. Étienne coal field to the works which were built near La Voulte.[13]

Developments on the Le Creusot-Blanzy coal field (Saône-et-Loire) were less rapid than those at St. Étienne. The attempts made in the 18th century to develop here an iron industry based on mineral fuel had been unsuccessful, and despite the local abundance of coal, the furnaces reverted to the use of charcoal. In 1836, such assets as remained were bought by the brothers Schneider, who developed here the works which remain one of France's chief sources of quality steel.[14] By the middle of the century the Le Creusot works comprised several blast furnaces and

[11] *La Sidérurgie française, 1864-1914*, Comité des Forges (Paris, 1914), p. 115-6.

[12] L. Babu, "L'Industrie métallurgique dans la region de Saint-Etienne," *Annales des Mines*, 9e série, Vol. XV (1899), pp. 357-460; see also Maxine Perrin, *Saint-Etienne et sa Region économique* (Tours, 1937), pp. 220 *et seq.*; *La Sidérurgie Française*, pp. 224-232.

[13] *La Sidérurgie française*, pp. 278-9.

[14] Jean Chevalier, *Le Creusot*, and M. Perrin, "Le Creusot," *Annales de Géographie*, Vol. XLIII (1934), pp. 255-274.

forty puddling furnaces, as well as other plants. They used ore from the Morvan and coke made from the coal of the Blanzy-Le Creusot field.[15]

A third area of growing importance lay to the north of the Massif Central. Here, in Bourbonnais and Berry, there had been an important charcoal iron industry, and some of the earliest successful attempts to use coke were made here. There was no lack of ore in the Jurassic series, and coal was carried down from the Commentry field to the furnaces built at Montluçon beside the Canal de Berry up and down which the ore boats plied.[16] Fifty miles to the northeast lay the furnaces of Fourchambault and Nevers, supplied with fuel by the small coal fields of the Loire and Allier valleys.[17]

On the western edge of the Massif there survived a charcoal iron industry in Limousin and Périgord, but a new industry, using mineral fuel from the local coal fields, had grown up at Decazeville, in the valley of the Lot.[18] To the south of the Massif, lastly, a new iron industry had sprung up on the Alais coal field. Here, too, attempts had been made in the 18th century to use mineral fuel in the furnaces,[19] but it was not until 1826 that the industry was practiced successfully.[20] Works were built at Tamaris and, a few years later, at Bessèges.

The only other iron industry which relied heavily on coal fuel lay in northern France. The forested margin of the Ardennes had long been the scene of an iron industry, for which the region with its numerous ore deposits and widespread forests offered peculiar advantages.[21] The northern coal field of France was opened up during the 18th century. In 1830, the first blast furnace works were established. Most of them lay to the east of Valenciennes, suitably placed to receive ore from the Ardennes, while remaining close to the coal mines. Two ironworks were also built on the small Hardinghen coal field, an outlier of the coal field of northern France, near Boulogne.

Between one-half and two-thirds of all the pig iron smelted in France around 1860 came from these furnaces which had been established in recent years on or near the coal fields. But the spread of the railway net was permitting some long-established works which lay remote from the coal fields to convert their furnaces from charcoal to coke. Among these were some of the furnaces in Lorraine[22] and

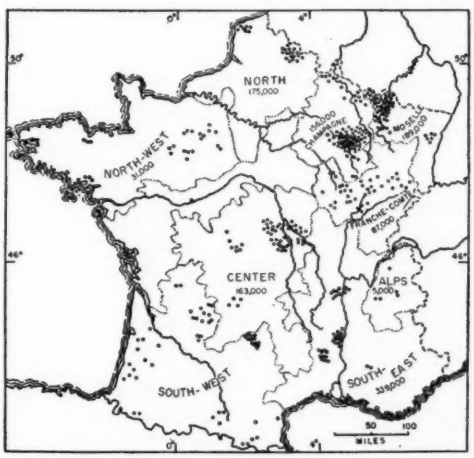

FIG. 4. Smelting works in 1864 (after *Le Comité des Forges*). The figures indicate output in metric tons for the regions indicated by five dotted lines. Boundaries as of 1870.

[15] *Berg- und Hüttenmännische Zeitung*, Vol. IX (1850), pp. 49-52.

[16] A. Vacher, "Montluçon," *Annales de Géographie*, Vol. XIII (1904), pp. 121-37, and F. Baraud, "L'Industrie à Montluçon," *ibid.*, Vol. XLIII (1934), pp. 364-371.

[17] "Beschreibung der Hütten zu Fourchambault und Guerigny," *Berg- und Hüttenmännische Zeitung*, Vol. IV (1845), pp. 154-9, 181-90, 209-14.

[18] "Beschreibung der Hüttenanlage von Decazeville," *Berg- und Hüttenmännische Zeitung*, Vol. III (1844), pp. 417-26, 464-71, 530-42, 570-81; Pillet-Will, "Examen analytique des usines de Decazeville," *Annales des Mines*, 3e série, Vol. III (1833), pp. 139-178; H. Coquand, "Note sur les minerais de fer des départements de l'Aveyron, du Lot, de Lot-et-Garonne, du Tarn, de Tarn-et-Garonne et de la Charente-Inférieure," *Bulletin de la Société Géologique de France*, Série 2, Vol. XVI (1848-9), pp. 328-365; *La Sidérurgie française*, pp. 273-5.

[19] M. de Genssane, *Histoire Naturelle de la Province de Languedoc*, Montpellier, 1776-9, Vol. I, pp. 9-18; and Achille Bardon, *L'Exploitation du Bassin Houiller d'Alais sous l'ancien régime* (Nimes, 1898).

[20] Jules Burat, *op. cit.*, p. 21; *La Sidérurgie française*, pp. 275-277.

[21] J. Laude, "Les Industries de la Vallée ardennaise de la Meuse, en France," *Bulletin de la Société de Géographie de Lille*, Vol. LXXVI (1934), pp. 141-165; R. Matton, "L'Industrie du fer dans le Bassin de Maubeuge," *Annales de Géographie*, Vol. XXXVI (1927), pp. 309-327.

[22] E. Gréau, *Le Fer en Lorraine* (Paris, 1908); Georges Hottenger, *L'Ancienne Industrie du Fer en Lorraine* (Nancy, n.d.); Axel Somme, *La Lorraine Métallurgique* (Paris, 1930).

département Haute Marne.[23] The de Wendel family was using coke, prepared from Saar coal, in its furnaces at Hayange and Moyeuvre in Lorraine. But a limit was set to expansion here by the fact that the local ores produced a pig iron rich in phosphorus. The puddling process did in fact reduce the phosphorus content, but the quality of the bar iron that resulted disqualified it for many uses.

Most of the furnaces, which appear in Figure 4 to be so numerous, were in fact very small. Many were active only in the winter months, when there was enough water in the streams to turn their water wheels. The furnaces and refineries of Haute Marne, Franche Comté, and of the northwest and southwest of France did little more than produce the simple iron goods required by a predominantly rural population.

THE DOMINANCE OF ORE-SUPPLY

After about 1860 a change slowly came over the French iron industry. The repeal of the ancient regulation by which a license, granted only after a governmental enquiry, was required before an industrial works could be established, encouraged the entrepreneur. The further extension of the railway system made it easier to transport both the raw materials and the finished products of the iron industry, and gradually created a national market for iron goods. In 1860 the reduction of import duties on iron and iron goods exposed France, hitherto partially insulated by high tariffs, to foreign competition.[24] The competition of cheap English ironwares contributed much to the extinction of ironworking at many of the lesser centers of the industry.

Lastly, technological advances that had been made in England revolutionized the industry. The inadequacy of soft or malleable iron for such goods as railway lines had long been realized. The ideal material for their fabrication was steel. But steel was very expensive, and cost alone precluded its use for many purposes for which it was eminently suitable. What the industry needed was a cheap and expeditious means of converting pig iron to steel. This was provided in the years 1855-60 by Sir Henry Bessemer. With the Bessemer converter steel could now be made very much more cheaply than soft iron had been made by the puddling process. A few years later the alternative and in many respects superior open-hearth method was introduced jointly by Pierre Martin of France and Werner Siemens of Germany.

In some instances the new processes were operated with complete success; in others they failed equally completely. The puddling process had been adequate to remove small quantities of phosphorus from pig iron by combination with the slag. But in the higher temperatures of the converter and open-hearth all the phosphorus passed back into the metal, making it brittle and intractable. The new processes afforded immense economies but greatly reduced the varieties of iron-ore that could be used. The older centers of smelting and refining continued to be active, though their relative importance declined rapidly unless they could use ores very low in phosphorus.

The ore deposits which lay close to the coal fields were in every instance of very restricted extent. Those of the St. Étienne region were already nearing exhaustion; those of the Ardennes and Morvan were individually very small and, in consequence, were very costly to mine. Even without the restrictions imposed by new technological considerations, most of the major centers of the French iron industry would have experienced difficulties in their ore supply.

The remedy was to import low phosphorus ore or so-called "Bessemer pig iron" which had been smelted from ore low in phosphorus. The chief sources of this ore were the Basque region of northern Spain, the Italian island of Elba, Algeria, and the Cumberland ore field of England.

Where the means of cheap transport were available, these imported ores were distributed to the older smelting centers. The furnaces of St. Étienne turned over very largely to ores from Mokta-el-Hadid in Algeria, which could be carried by barge up the Rhône.[25] Le Creusot experienced much greater difficulties. It continued to use the local, phosphoric ores

[23] Marcel Bulard, "L'Industrie du Fer dans la Haute-Marne," *Annales de Géographie*, Vol. XIII (1904), pp. 223-242; 310-321.

[24] A. L. Dunham, "The influence of the Anglo-French Treaty of Commerce of 1860 on the Development of the Iron Industry in France," *Quarterly Journal of Economics*, Vol. XLI (1927), pp. 317-337.

[25] L. Babu, *op. cit.*, p. 402.

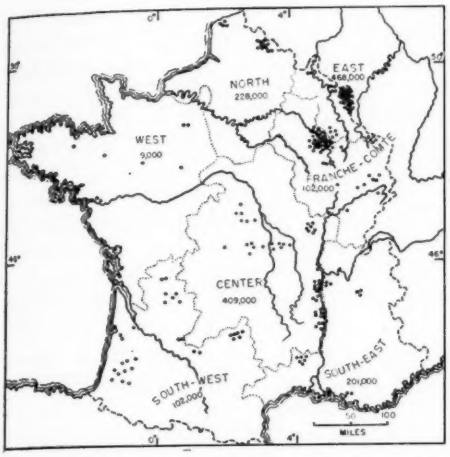

FIG. 5. Blast furnaces in 1878 (after *Le Comité des Forges*). The figures indicate output of pig iron in metric tons for the regions indicated by dotted lines. Boundaries as of 1871–1918.

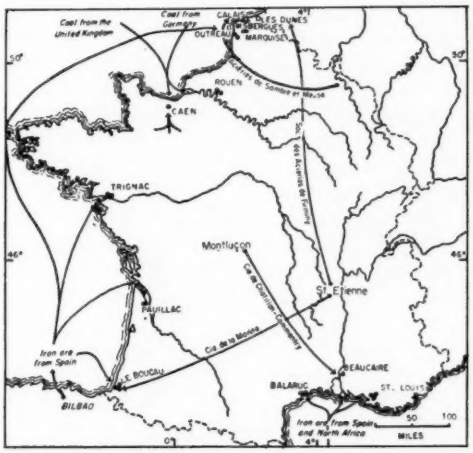

FIG. 6. Coastal iron works, established in the second half of the nineteenth century. The black dots indicate smelting works; the small open squares, steel works using imported pig iron.

for foundry iron,[26] but for its steel works it used ores from the French Alps or imported ores from Spain or North Africa.[27] But where this was not possible, the furnaces had either to close or continue to produce pig iron fit only for the foundry or for the puddling furnaces. A comparison of Figures 4 and 5 shows how extensive was the closing down of smelting works.

This new dependence upon imported ores suitable for Bessemer pig iron led to the use of smelting industries on the coast or near navigable rivers.[28] This phase in the history of industrial location manifested itself also in Germany and is of importance still in the United Kingdom and the Netherlands (Fig. 6). The location of the earliest of these coastal works was perhaps accidental, insofar as they were established before the need to use imported ore had become as pressing as it was after 1860. These included the works at Marquise and Outreau in northern France.

The Saint-Louis works were built near Marseille just before the new technology was introduced. Others were established, for the specific purpose of smelting non-phosphoric ores, at Balaruc and Beaucaire, near the Rhône delta; at Trignac and Pauillac, on the west coast of France; at Le Boucau, on the Gascon coast near Bayonne; and at Isbergues, Calais and Rouen, all on or near the north coast. A coastal works established at Caen, in Normandy, differed from the rest in that a local ore from Normandy was used, and smelted with fuel brought in by sea. The rest were located for the specific purpose of using imported ores. Five of these coastal works had steel works as well as blast furnaces. The others sent pig iron to be refined in steel works situated in the interior of France. In most instances the coastal works were built, owned, and operated by a parent concern which carried on the fabricating processes in the interior of the country.

DOMINANCE OF TECHNOLOGY

The changes in the location of French iron and steel works, described in the previous section, were a response to changes in the field of technology, namely, the adoption of the Bessemer and Siemens-Martin processes, and the consequent demand for ore low in phosphorus. Throughout these years the minette of eastern France was little used, though attempts were being made to modify the Bes-

[26] Phosphorus was actually an advantage in foundry iron, as it rendered the metal more fluid and easier to cast.

[27] "Excursion to Le Creusot," *Journal*, Iron and Steel Institute, 1878, pp. 512-529.

[28] *La Sidérurgie française*, 241-263; compare Colin Ross, *Die Entstehung von Grosseisenindustrie an der deutschen Seeküste* (Berlin, 1911).

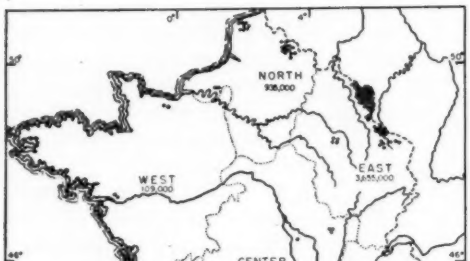

FIG. 7. Blast furnace works in 1913 (after *Le Comité des Forges*). The figures indicate the output of pig iron, in metric tons, for the regions shown by dotted lines.

semer and Martin processes so that they could use a phosphoric metal. Although the extent of the minette deposits was not fully known and their resources were underrated, the French iron-masters were more than ready to use them as soon as this became technically possible. This happened in 1878 when Gilchrist Thomas, in England, demonstrated that a lining of basic chemical composition would permit a basic slag, capable of removing the phosphorus from the metal, to be formed.

The speed with which the basic process was adopted in many parts of Europe is evidence of its great importance. In France the basic process was employed in French Lorraine as early as 1879, and within a decade French Lorraine was producing about 60 percent of French pig iron. A comparison of Figures 5 and 7 shows how strongly marked was this concentration of the smelting industry on the Lorraine ore field.

The minette, which now began to be used in quantity, is a low-grade ore. While its extraction was relatively inexpensive, it became, with less than 32 percent of metal, very costly to transport. At the same time, improvements in blast-furnace design were bringing about economies in fuel consumption. It became increasingly profitable to smelt minette on the ore field with coke imported from whatever sources might be available.

In effect, the iron- and steel-using concerns in the Center transferred their interests from the smelting works located on the coast only a few years before to newly built works on the Lorraine ore field (Figure 8). An interesting case study is furnished by the Châtillon-Commentry company.[29] Its original works consisted of charcoal furnaces in the province of Berry. Subsequently coal from the Commentry field came to be used for its furnaces near Montluçon. Exhaustion of the better local ores, combined with the desire to use the con-

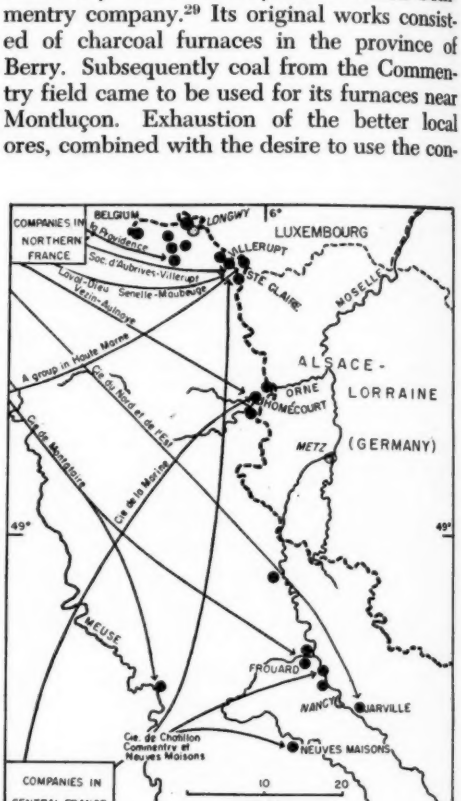

FIG. 8. Smelting works established on the Minette ore field of Lorraine, and their dependence on steel-refining and finishing works in other parts of France. Boundaries as of 1871–1918.

verter and open hearth for steel-making, led to the erection by the company of blast furnaces at Beaucaire, on the Rhône about 40 miles from its mouth. These furnaces smelted African, Spanish, and Elban ores, and sent the pig iron obtained back to the company's steel works at Montluçon. It soon became evident that greater economies could be achieved by converting at least part of the pig iron to steel

[29] *La Sidérurgie française*, pp. 252-254.

at Beaucaire and sending the half-finished steel goods to Montluçon. It is possible that this geographical break-down of the industry might have continued if the introduction of the basic process had not altered the relative importance of the varieties of ore. For a number of years the Montluçon works continued to use steel made from the low-phosphorus iron of Beaucaire. But the Beaucaire works were eventually closed, and the Châtillon-Commentry company first acquired the Ste-Claire and Villerupt furnaces, near Longwy, and then merged with another Lorraine group to form the *Cie. des Forges de Châtillon, Commentry et Neuves Maisons.*[30] New blast-furnaces were built at Neuves Maisons, about six miles southwest of Nancy; a steel refinery was added and steel "semis"[31] were supplied to the fabricating and engineering works in central France. This geographical division of the several processes still exists.

In thus acquiring smelting and steel works in Lorraine, the *Cie. de Châtillon-Commentry* was only following the example of steel-making and steel-using firms in other parts of France. In the metallurgical centers of the St. Étienne region, and in Northern France and the Ardennes, there was, in the second half of the century, a growing shortage of ore. Even before the announcement of the Gilchrist Thomas discovery, some firms in these areas interested themselves in the Lorraine ore field. Iron smelted from minette was, at the least, suited for casings, and the puddling process, by which it could be converted into a serviceable soft iron, was not everywhere written off as uneconomic.

Furnaces at Jarville, near Nancy, were built as early as 1866 by a firm at Valenciennes, whose holdings later became the nucleus of the *Société du Nord et de l'Est.* A number of small firms in the Meuse Valley, having exhausted the possibilities of charcoal-iron in the Ardennes, bought or built furnaces in Lorraine. Among these were the companies of Maubeuge, Laval-Dieu, La Providence, Vezin-Aulnoye, and Aubrives. The Cie. de Montataire, whose fabricating works lay mainly at Creil, north of Paris, acquired the iron and steel works of Frouard. The *Cie. de la Marine* of St. Étienne in 1902 took over the Homécourt furnaces and steel works, thus forming the *Cie. de Forges et Aciéres d'Homécourt et de la Marine.* In many instances, these small, double-barrelled companies were absorbed by larger concerns, but in the years preceding the First World War it was becoming normal for an iron and steel firm to have smelting and perhaps steel works in Lorraine and engineering and fabricating plants situated at the older centers of the French metallurgical industry.

Throughout these years a part only of the Lorraine ore field lay in France. A similar development was taking place on the minette deposits of Lorraine annexée. German firms, with their principal works in the Ruhr and Saar, were building blast furnaces and steel works in German-held Lorraine and used these to supply raw materials to their finishing works elsewhere in Germany. Even Belgian works, though to a more limited extent, became active in the minette region. The two large concerns of ARBED and HADIR[32] had the effect of linking the iron ore and iron and steel capacity of the minette region with iron industries elsewhere.

The iron ore of Normandy was, like that of Lorraine, phosphoric. It had formerly been used locally for the production of foundry iron, but its importance diminished during the nineteenth century.[33] After the introduction of the basic process, the value of these ores increased, but remoteness from a source of fuel detracted from their usefulness. In 1910, however, a company was formed for the purpose of using them in blast furnaces situated near the Normandy coast at Caen. Fuel was to be brought in by sea. There was an important German

[30] *La Sidérurgie française,* p. 175; Axel Somme, *La Lorraine métallurgique,* p. 19.

[31] "Semis," or *Halbzeuge* in German, are half-finished steel goods, and rolled goods, such as strips, sheets, and wire.

[32] These titles indicate respectively *Aciéries réunies de Burbach, Eich Dudelange* et *Hauts fourneaux et aciéres de Differdange, St. Ingbert et Rumelange.* Burbach and St. Ingbert lay near Saarbrücken; the other named places were in Luxembourg. Eich however was only of historical importance. It was the seat of an early Luxembourg company (Metz et Cie.) but was not near the ore field and its importance was declining. German participation, through Deutsch-Luxembourg, was very strong in HADIR.

[33] Jean de Maulde, *Les Mines de Fer et l'Industrie métallurgique dans le département de Calvados* (Caen, 1916); also H. V. Janau, "The Iron Ores of Normandy," *Scottish Geographical Magazine,* Vol. XLI (1925), pp. 266-284.

participation in this company, and its relationship to a parent company (Thyssen) in the Ruhr was in fact similar to that of the German subsidiaries in Lorraine. It differed only in being more remote from Germany, in lying in non-German territory, and in relying on sea transport for fuel and part-finished goods.

THE INTER-WAR YEARS

At the end of the First World War, Alsace and Lorraine annexée were returned to France. In the previous forty years France had built up in those parts of the minette region which she had retained a smelting and steel industry as large as that which the Germans had developed on their side of the boundary. In 1919 a pig iron capacity of about 3,750,000 tons and a steel-making capacity of 2,250,000 were added to France.[34] Developments in Germany during the following years greatly reduced the German dependence on Lorraine for pig iron and steel "semis," and France was obliged to develop further her own finishing industries in order to use her increased crude steel production. War damage had been considerable in the metallurgical works of both the north and the east of France, and it was several years before the conditions of overproduction resulting from the inclusion in France of the former German industry, became apparent.[35] Furthermore, rebuilding and reconstruction created a large though temporary demand for metal products.

The iron and steel works in northern and eastern France, where damage had been severe, were rebuilt and left in a very efficient state.[36] On the other hand little modernization took place in other centers of French metallurgy, and investment here was inadvisable in view of the condition of incipient over-production.[37] In fact, the economic depression combined with the excess productive capacity to render the French metallurgical industry highly uneconomic in the 1930's.

The marginal iron and steel works were those located in the older industrial centers, the Centre, the south and the west, where the supplies of ore and fuel were inadequate and equipment was less modern. Under these stringent conditions, a number of works were closed here, and the predominance of the minette region and the north in both iron-smelting and steel-making was further emphasized:

Pig-iron production	*1927*	*1952*
Minette region	78.6%	77.9%
North	10.9%	12.8%
Rest of France	10.5%	9.1%
Steel production		
Minette region	69.7%	65.5%
North	15.6%	21.5%
Rest of France	14.7%	13.0%

The rate of obsolescence of equipment in iron and steel works is fairly rapid. Furnaces and equipment built in northern and eastern France at the end of the First World War were already old by the beginning of the Second World War. Most of that in other parts of France was obsolete. By contrast, there had been very extensive modernization and rebuilding in the German industry in the 1930's. The French industry remained, in those branches which it practiced, too big for the domestic market, too uneconomic to be able to command a large export trade, and weak in certain newer branches of steel production.

THE MONNET AND SCHUMAN PLANS

A little over a year after the end of the Second World War, Jean Monnet prepared the plan which bears his name for the economic rehabilitation of France. In his first report, he emphasized the urgent need for re-equipment and modernization of the French industrial plant.[38] In the sphere of iron and steel, the plan envisaged an output of crude steel rising to 11 million tons in 1950 and later to 15 millions.[39] Of paramount importance, however, was the modernization rather than the extension of iron and steel capacity. Monnet called for the grouping of iron and steel works to produce larger and more efficient units of pro-

[34] *Die Wirtschaftliche Entwicklung Elsass-Lothringens, 1871-1918* (Frankfurt-am-Main, 1931), pp. 169-231.

[35] William F. Ogburn and William Jaffé, *The Economic Development of Post-War France* (New York: Columbia University Press, 1929), pp. 33-26; R. Jordan, "The French Iron and Steel Industry," *London and Cambridge Economic Service, Special Memorandum No. 20*, 1936, pp. 9-10.

[36] Robert Cahill, *Economic Conditions in France* (London: Department of Overseas Trade, 1934), pp. 213-216.

[37] J. Chardonnet, *La Sidérurgie française* (Paris, 1954), pp. 203-209.

[38] *Rapport Général sur le Premier Plan de Modernisation et d'Equipment*, November, 1946, pp. 9-12.

[39] *Ibid.*, pp. 44-46.

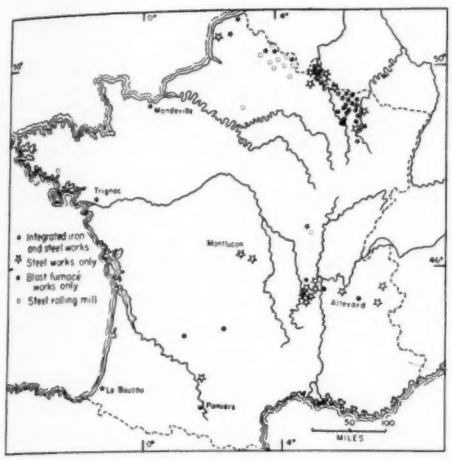

FIG. 9. Distribution of iron-smelting and steel-making works in France, 1955 (excluding the Saar Territory).

duction, and for a higher degree of specialization as between works.

The original plan called for the erection of two hot rolling mills of the largest size, one at Denain in northern France, the other near Thionville in Lorraine; the installation of a number of smaller rolling plants, both hot and cold, and the rebuilding and extension of several smelting and steel-making works. As economies in the use of blast-furnace coke are a major consideration to the French industry, great emphasis was placed on coking and ore-preparation works.

The implementation of the plan lagged, and crude steel production has not yet quite reached this level. This is attributable in part to difficulties, not wholly foreseen by Monnet, in capital investment; in part to a shortage of steel scrap and other technical problems.[40] Notwithstanding these difficulties, the French industrialists have themselves prepared plans, running through 1957, for further increases in iron and steel production capacity. These would bring the total output up to at least 15,400,000 tons, and a production of 16,900,000 tons was foreseen by 1960.[41] This probably exceeds the market capacity, and these over-optimistic plans have been severely trimmed by the Iron and Steel Modernization Committee of the Monnet Planning Commission.

Even within their reduced limits, the new plans represent for France a formidable undertaking, but the success which ultimately attended the Monnet Plan augurs well for the future of other plans. The smoothness, efficiency, and success of the re-equipment and modernization of large segments of French industry stands in marked contrast with the inability of the country to achieve political stability.

The supply of iron ore is not expected to be a problem to the expanding industry. With the bulk of the smelting capacity located on or relatively near the minette field of Lorraine and the recent electrification and improvement of the railroad between Lorraine and northern France, the supply of ore to the furnaces has been a relatively small factor in total costs. The iron-ore mines of Lorraine have been extensively re-equipped and are now very efficient.[42]

The supply of metallurgical coke might be held to be a more serious obstacle to iron and steel expansion. The coal of both the Saar and Lorraine is relatively high in volatile constituents, and under ordinary conditions yields only a soft and friable coke. The French smelting industry was formerly heavily dependent on imported coke and coking coal, and by far the most important source was Germany.[43] There can be no doubt that in the past the German coal producers discriminated against French purchasers, and in recent years the French industrialists have experienced considerable difficulty in obtaining adequate supplies of satisfactory metallurgical fuel. They claim, however, that these difficulties have largely been overcome.

The European Community for Coal and

[40] "The French Steel Development Plan," *Monthly Statistical Bulletin, British Iron and Steel Federation*, February, 1953; "Steel Developments in France," *ibid.*, August, 1955; *France*, Overseas Economic Surveys, H. M. Stationery Office (London, 1953), pp. 41-45.

[41] *The European Steel Industry and the Wide-Strip Mill*, Economic Commission for Europe, United Nations (1953), pp. 92-97; see also *European Steel Trends*, United Nations (1949).

[42] "Technical Achievements in French Steel," *France Actuelle*, Oct. 1, 1955; *Recent Advances in Steel Technology and Market Development*, Economic Commission for Europe (1955), pp. 3-6.

[43] Guy Greer, *The Ruhr-Lorraine Industrial Problem* (London, 1925).

Steel has removed at least the more obvious forms of national discrimination, and to this extent has benefited the French. Furthermore, a group of Lorraine industrialists has acquired coal mines in the Ruhr in order to ensure their supply of fuel. More important, however, have been the experiments, in large measure successful, in blending and coking the very gassy coal of Lorraine and the Saar. In 1950, about half a million tons of metallurgical coke was made from Lorraine coal. By 1956 this is expected to rise to 2,600,000, or nearly a quarter of the total French requirement.[44] It is anticipated that consumption of imported metallurgical fuel will drop from 40 percent of the earlier total to about 27 percent of a much increased total.[45]

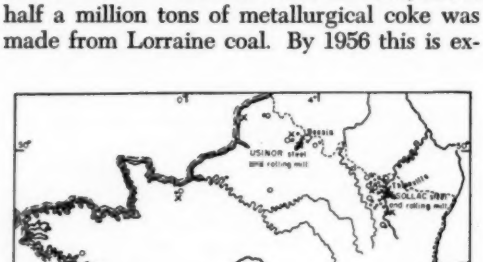

FIG. 10. Distribution of construction and modernization projects carried out under the Monnet Plan (after *Monthly Statistical Bulletin, British Iron and Steel Federation*, Feb., 1953, and August, 1955).

The Lorraine coal mines lie no more than about 40 miles from the minette ore field. Their known reserves are large and amount to a great deal more than half the French total.[46] At present the cost of blending and coking Lorraine coal is somewhat in excess of the cost of handling the more familiar types of coking coal, but if this margin can be reduced, the close proximity of ore and fuel could make Lorraine not only one of the most important but also one of the cheapest sources in the world of iron and steel.

With success almost assured of producing a satisfactory coke from the soft Lorraine coal, the most serious geographical problem remaining for the French steel industry is its location. Not only is it situated relatively far from its chief markets, but it lacks the cheaper means of transportation. The Ruhr, the chief rival in Europe in the production of steel goods, has the advantage of cheap water transport to its chief ports. The French industrialist must rely on road and rail. It would be unfortunate if on this account the difference between rates c.i.f. for steel goods are greatly in excess of quotations f.o.b. at Thionville or Longwy.

Figure 9 illustrates the distribution of the French iron and steel works in 1955. Figure 10 shows the location of the modernization and construction projects under the Monnet Plan. The predominance of Lorraine further asserts itself. An industrial concentration which began with the introduction of the basic process is further emphasized by the most recent developments in coke-oven practice.

[44] *Recent Advances in Steel Technology, op. cit.*, pp. 7-10.

[45] "Steel Developments in France," *op. cit.*, p. 10.

[46] *European Steel Trends in the Setting of the World Market*, Economic Commission for Europe (1949), p. 116.

THE ROLE OF NUCLEAR POWER IN EUROPE'S FUTURE ENERGY BALANCE*

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Over the last several years a series of studies has been published analyzing the effects of the atomic age on the energy requirements and economic growth of individual countries, continents, or the world as a whole.[1] The common aim of all these studies has been to evaluate future progress in terms of an increased standard of living which is expected to result in increased energy demands.[2]

One measurement of a country's wealth is the amount of power available. The increasing use of coal, hydro power and petroleum contributed greatly to the economic growth and political power of western Europe. Now Europe again has come to a crossroad. With increased demands on energy requirements and insufficient raw materials or increased costs of mining, the future of Europe's energy balance is at stake. Coal, the workhorse of Europe's power supply, has become more and more expensive and limited to certain types and is unable to satisfy the increased demands. All advantageous hydro sites will have been used within 7 to 30 years, the shorter period for the more highly industrialized countries of Western Europe. Therefore, most of the increased demands for electricity during the immediate future must be covered by importing petroleum, most of which is being shipped from the unstable Middle East.

Nuclear power[3] therefore has been harnessed just in time.[4] Nuclear power stations

*I am indebted for many fruitful suggestions to Dr. Edward A. Ackerman of Resources for the Future, Washington, D.C., Professor Stephen B. Jones of Yale University, Professor Richard Rush of the Department of Geology of The University of Texas, and Monsieur Pierre Sevette, Chief Electric Power Section, Industry Division, Economic Commission for Europe, United Nations, Geneva. Appreciation for assistance in making information available and the checking of numerous statistical data is also extended to Mr. J. A. van den Heuvel, Head, Fuel and Power Division, Organization for European Economic Cooperation, Paris, France, to Baurat Ing. Erich Heller, Innsbruck, Austria, and to the Union Internationale des Producteurs et Distributeurs d'Electricitie (UNIPEDE). Special appreciation is expressed to my colleague, Professor Emmett L. Hudspeth, Director, Nuclear Physics Laboratory of The University of Texas, who spent considerable time with me explaining elementary background information relating to nuclear fission and defining certain technical terms. A grant from the Social Science Research Council in 1952 permitted me to visit numerous hydro and thermal installations in France, Switzerland, Austria, Italy, and Yugoslavia and to establish contacts with O.E.E.C. in Paris and E.C.E. in Geneva. The Graduate Research Institute of The University of Texas kindly provided research assistance.

[1]United Nations, "World Energy Requirements in 1975 and 2000," *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy* (hereafter quoted as *International Conference*), Vol. I (New York: United Nations, 1956), pp. 3–33; E. S. Mason and staff, "Energy Requirements and Economic Growth," *International Conference*, Vol. I, pp. 50–70; P. Ailleret, "Estimate of Energy Requirements," *International Conference*, Vol. I, pp. 34–37.

[2]It is realized that in addition to present common sources of energy—those released by combustion of fossil fuels and the energy resulting from falling water—nuclear energy and, at a much slower tempo, solar energy will play an ever-increasing role. But besides these sources, research has continued on a number of alternate or unconventional sources of energy, e.g.: volcanic heat to generate steam, which is commercially exploited in Italy; the windmill, which has been used in some parts of the world for centuries; utilization of the height of tides and the temperature differences between the ocean floor and the surface are among more recent experiments. Farrington Daniels, "Alternate Energy Sources (Unconventional Types)," *International Conference*, Vol. I, pp. 77–84, and L. Bauer, T. Breitenstein and others, "Uebersicht ueber die Entwicklung der nationalen Energiewirtschaften von 1950–1954," advanced print I-A, *5th World Power Conference* (Vienna, 1956).

[3]Walker L. Cisler, "The Need for Broad Development of Atomic Energy," paper presented at Atomic Industrial Forum, Inc., May 23–24, 1955, private printing.

[4]Economists generally have come to the conclusion that energy requirements can be expected to increase at a rate of 2.5 to 3 percent per annum in Western Europe and more than three percent in Eastern Europe. For detailed discussions estimating future energy requirements see the papers presented by United Nations, "World Energy Requirements in 1975 and 2000," *op. cit.*, E. S. Mason, "Energy Requirements and Economic Growth," *op. cit.*, P. Ailleret, "Estimate of Energy Requirements," *op. cit.*, and Palmer C. Putnam, *Energy in the Future* (New York: D. van Nostrand, 1953). For a discussion of the methods used in arriving at some of these esti-

will first test different technological developments and compare different types "from the point of view of economics and also of reliability and safety in operation."[5] For many countries of Europe, energy from nuclear power will ultimately become an important additional source of supply, especially for those countries where present energy resources are rapidly becoming insufficient to supply constantly increasing demands.

At the outset the author wishes to express the aim of this study, determined by its geographic delineation. The problem of actual cost, both for reactor and fuel economy,[6] is left to the economist. Strictly technical problems are left to the engineers and nuclear physicists, all of whom seem to assume that as our technical knowledge increases, actual experience is gained with different types of reactors, and as a result costs per kwh will decrease. Ultimately nuclear energy will become competitive with existing sources of energy, even in those countries that have large reserves of fossil fuels.

Having eliminated detailed considerations of costs and technical problems, this study begins by briefly surveying and summarizing the present European energy situation. Specialists from all countries agree that international cooperation in the use of all natural resources and international exchange of electric power is essential to satisfy energy requirements in years to come.[7]

These preliminary considerations bring us to the core of this study: the future role of nuclear energy in Europe. In evaluating this future role, the geographer must consider four key problems: (1) the availability of raw materials for nuclear fuels, (2) the location of nuclear reactors and nuclear power plants, (3) a survey of present nuclear efforts in Europe, and (4) the importance of joint undertakings with regard to specialized facilities, research, training, and actual power production. All during these investigations it will be of importance constantly to relate this new form of energy to existing conventional energy sources.

The International Conference on the Peaceful Uses of Atomic Energy, the availability of an increased number of publications from all over the world,[8] and detailed discussion published by European countries most advanced in nuclear research and most anxious to build atomic reactors for the production of commercial nuclear power—The United Kingdom, Sweden, and France—permit not only the accurate reporting of present developments, but make it possible to draw some conclusions as to possible developments during the years to come.[9]

EUROPEAN ENERGY SITUATION

At the end of World War II, Europe's energy system was completely disorganized

mates see United Nations, Economic Commission for Europe, Committee on Electric Power, *Nuclear Energy and the Production of Electric Power in Europe*, E/ECE/EP/181 (Geneva, 1956), pp. 7–13, and United Nations, Economic Commission for Europe, *Methods Employed for the Determination of Electric Power Consumption Forecasts*, E/ECE/224-E/ECE/EP/179 (Geneva, 1956).

[5]John Cockcroft, "The Future of Atomic Energy," *International Conference*, Vol. XVI (New York: United Nations, 1956) pp. 121–125.

[6]Based on the papers presented at the International Conference on the Peaceful Uses of Atomic Energy, the 5th World Power Conference, and those made available by the Atomic Energy Commission, the problem of nuclear economy is threefold: (1) increasing the amount of energy which can be extracted from one ton of uranium and thorium, (2) recycling of fuel in thermal reactors several times, which will result in increased energy extraction, and (3) use of the breeding principle which should permit extraction of a great part of the fissionable energy of uranium. Frank H. Spedding, "Atomic Fuels," advanced print, *5th World Power Conference* (Vienna, 1956).

[7]George W. Hoffman, "Toward Greater Integration in Europe: Transfer of Electric Power across International Boundaries," *The Journal of Geography*, Vol. IV (April 1956), pp. 165–176.

[8]Developments in the U.S.S.R. are not part of this investigation, but information available with regard to developments in Poland, Czechoslovakia, Hungary, Rumania, Bulgaria, and Albania are included in these considerations. For reasons of convenience, this study divides Europe into Western and Eastern Europe, including with Western Europe all countries outside the Soviet orbit. Whenever Europe as a whole is mentioned but certain countries are omitted because of lack of detailed information, this fact will be recorded in footnotes.

[9]In a recent study of mine, *op. cit.*, special emphasis was given to the immediate European energy problem—increasing supplies with the means available largely through the transfer of electric power across international boundaries. The present study is thought of as a continuation of this study, the overall problem still being "Europe's future energy balance."

Mines were in need of much repair work, dams had been destroyed and power plants bombed out, generators were in need of overhauling or needed to be completely replaced, refineries had been destroyed and those remaining were insufficient to serve energy-hungry Europe. Victor and vanquished shared similar problems to varying degrees.

Slowly, and after 1948 with a quickening tempo, Europe's energy situation improved, but not without relapses. Many will remember the catastrophic winter of 1947 in England, when abnormal snow conditions brought about a complete breakdown of the British energy supply. United States economic and technical assistance contributed greatly to nearly every country in Europe. Only the changed political situation after 1947–48 gave greater and greater emphasis to Western Europe's recovery. Marshall Plan aid and private investments[10] contributed to the building of new hydro and thermal power facilities, to the modernization of coal mines, mining equipment, and oil refineries and to many other ventures.

The rapid expansion in industrialization and transportation, and a slower but steady increase in living standards during the last 10 years are changing greatly the whole European energy balance.[11] Coal, the backbone of European energy supplies for generations, has been unable to meet the rising demands since World War II. Hydro power is available only in a number of restricted areas, and natural gas is still little used in Europe. The great change has been the rapid increase in the consumption of oil, especially in Western Europe. Practically all increased energy consumption in Western Europe is satisfied by increased imports of oil, some increase from petroleum discoveries, and additional hydro

[10] American oil companies alone invested close to three-quarters of a billion dollars in reconstruction and expansion of Western European facilities.

[11] After a slow start industrial production in the countries within the Soviet orbit has generally surpassed 1937 production. While consumption has remained stable or in some areas has even declined, the many new industrial ventures have demanded increased energy supplies.

TABLE 1. — PRODUCTION AND CONSUMPTION OF ENERGY IN EUROPE
1937, 1955

Energy source	Production[1]				Consumption[1]			
	Million metric tons		Percent		Million metric tons		Percent	
	1937	1955[2]	1937	1955[2]	1937	1955[2]	1937	1955[2]
Europe excluding U.S.S.R., including Turkey								
Coal	580	616	81.0	69.6	542	631	77.4	63.3
Lignite	78	135	10.8	15.3	78	135	11.0	13.4
Crude petroleum	8.9	22.2	1.2	2.5	32.5	119.7	4.6	12.0
Natural gas[3]	4.0	12.6	0.6	1.4	4	12.6	0.6	1.4
Hydroelectricity	45.5	99	6.4	11.2	45.5	99.0	6.4	9.9
Total	716.4	884.8	100	100	702.0	997.3	100	100
Western Europe (O.E.E.C. Countries)[4]								
Coal	488.1	477	81.8	69.9	472	509.2	77.6	63.7
Lignite	72.3	105	12.2	15.5	72.3	105.0	11.9	13.2
Crude petroleum	0.56	9.2	.09	1.3	28.6	93.5	4.7	11.7
Natural gas[3]	0.05	6.7	.01	1.0	0.05	6.7	.01	0.8
Hydroelectricity	35.4	84.4	5.9	12.3	35.4	84.4	5.8	10.6
Total	596.41	682.3	100	100	608.35	798.8	100	100

[1] Figures supplied by ECE, United Nations, Geneva.
[2] Provisional figures (Table compiled July 1956).
[3] Includes methane gas from coal mines.
[4] Figures supplied by OEEC, Paris.
Conversion: 1 ton of lignite=0.3 (average) ton of bituminous coal; 1 ton of petroleum=1.5 tons of bituminous coal; 1,000 m of natural gas=1.33 tons of bituminous coal; 1,000 kwh of electricity=0.7 ton of bituminous coal (pre-war), 0.6 ton of bituminous coal (post-war); some OEEC figures use 0.4 ton of bituminous coal for post-war. Western Europe: net inland consumption of petroleum products multiplied by 1.08 to take account of refinery losses. Eastern Europe: crude oil production.

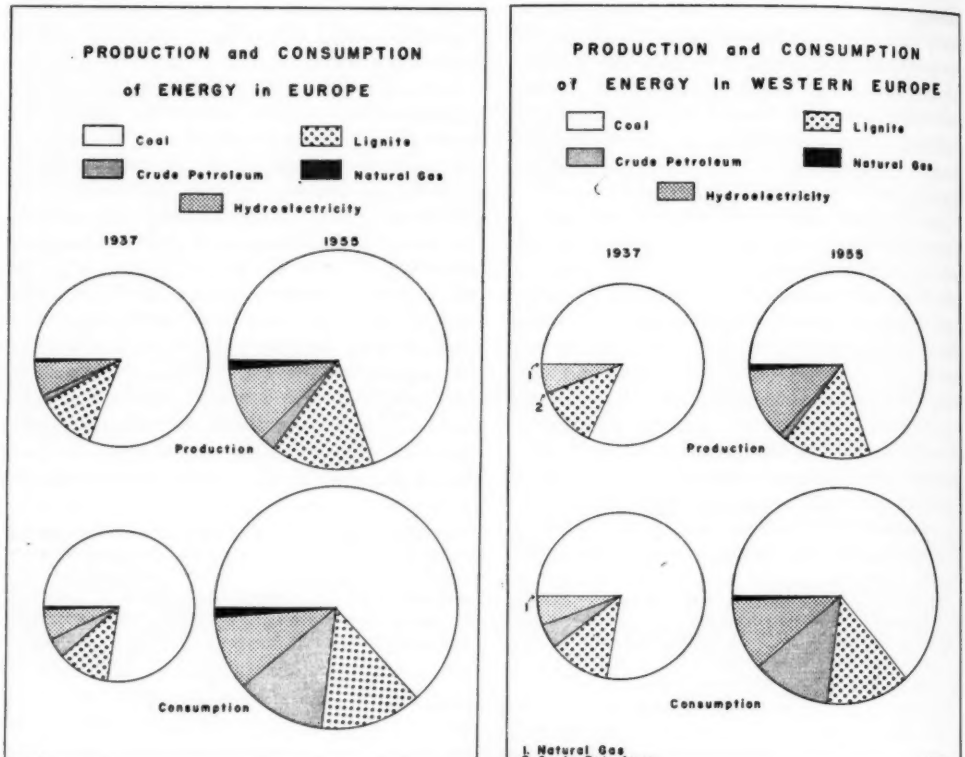

FIGURE 1

power. Table 1 and Fig. 1 give an indication of the changes in European production and consumption since 1937. With good hydro sites becoming scarce, Europe's energy balance in the years to come will have to turn more and more toward importing petroleum to satisfy increased demands.

Why has the energy resource position changed and how do the energy resources of coal, oil, natural gas, and water satisfy present European energy demands? These questions have been studied and the results published in numerous papers.[12] Therefore only a brief summary is needed here. But the answer to these questions is important for an understanding of the problems of nuclear energy and its contribution and role in Europe's future energy supply.

Coal

Coal (bituminous and lignite) is the main contributor to Europe's energy economy, as shown in Table 1. Coal supplies contributed 88 percent of Europe's consumption in 1937, but only 77 percent in 1955. While obviously declining, it will continue to be of major

[12] *Nuclear Energy and the Production of Electric Power in Europe, op. cit.*; J. A. van den Heuvel, "The Place of Oil and Natural Gas in the European Economy," paper presented at World Petroleum Congress, Rome, June, 1955; and United Nations, Economic Commission for Europe, Industrial Division, *Relationship between Coal and Black Oils in the West European Fuel Market*, E/ECE/191 (Geneva, 1954). For an up-to-date summary of the energy situation in the O.E.E.C. countries see report by group of experts, *Europe's Growing Needs of Energy: How Can They Be Met?* (Paris: The Organization for European Economic Cooperation, May 1956), Appendix III, pp. 75–102.

TABLE 2. – OUTPUT OF HARD COAL IN EUROPE IN SELECTED YEARS AND PROBABLE RESERVES[1] (IN MILLIONS OF METRIC TONS)

Country	Probable reserves	Production 1937	1947	1952	1953
Belgium	3,000	30	24	30	30
France	12,000	44	45	55	53
Saar	8,000	13	10	16	16
Western zones of Germany	67,000	138	71	123	124
Netherlands	4,000	14	10	13	12
United Kingdom	171,000	244	201	230	228
Other West European countries	15,000	6	17	18	19
Czechoslovakia	6,000	17	16	20	20
Poland	136,000	66	59	84	89
Other East European countries	2,000	5	4	6	6[2]
Total Europe	424,000	577	457	595	597

[1]*Source:* Economic Commission for Europe, *Relationship between Coal and Black Oils in the West European Fuel Market*, E/ECE/191 (Geneva, 1954), p. 47, which is taken from World Power Conference, Washington, *Statistical Yearbook*, No. 4, 1936 to 1946, and No. 6, 1948 to 1950; *Glueckauf*, Essen, Vol. 89 (1953), p. 595; and B. Roga and L. Wnekowska, "Analiza Paliw Stalych" (Warsaw, 1952), pp. 31 and 34.

[2]Estimate.

importance for many, many years to come.[13]

Reserves of coal are considerable as can be seen from Table 2, but the mining of these reserves becomes more and more difficult due to greater depth of the mines and thinner seams. A large percentage of the present output is obtained from pits which are more than 40 years old. Such mines are located, for the most part, in the Ruhr, the United Kingdom and some in France and Belgium. Mines in Silesia and Lorraine are in much better condition. Obviously there is a limit to the amount of coal which can be mined economically.

Of major importance to European industrial production is the fact that Europe's two most important coal producing countries—the United Kingdom and Western Germany—already have been forced to rely upon imports from the United States.[14] Also, shortages of certain qualities make imports necessary. France, for example, is obliged to import approximately 15 million tons each year.[15] These factors, plus a constantly dwindling labor force in the coal industry, under present conditions of full employment, make the use of coal increasingly costly.[16]

For these reasons the annual increase in production has been estimated at only one percent (for bituminous coal only) per annum until 1965 and "the maintenance of the output in that year until 1975" for the O.E.E.C. countries. But the production in Europe as a whole varies from country to country. Poland, for example, estimates an increase of 25 percent in her present five-year plan. The Ruhr, the French and Belgian coal fields expect no increase at all. The Netherlands anticipate a small decrease, and the United Kingdom, Europe's largest producer, has planned a 10 percent increase by 1965, even though the latest annual report of the National Coal Board is most pessimistic about the United Kingdom's reaching this goal. The effect of the plans and investments of the Coal and Steel Community "has yet to be seen but it might well, in the coal-producing countries concerned, improve the situation by promoting higher output at lower cost."[17]

[13]The President's Materials Policy Commission, *Resources for Freedom*, Vol. III: *The Outlook for Energy Sources* (Washington: Government Printing Office, 1952), p. 29, estimates, for example, that 52 percent of Western Europe's energy consumption in 1975 will still come from solid fuels.

[14]In 1955 the O.E.E.C. countries had a net import of 29 million tons of coal, of which the United Kingdom and Western Germany accounted for more than 10 million metric tons. *Relationship between Coal and Black Oils in the West European Fuel Market, op. cit.*, pp. 52–55, discusses the present and future coal needs, pp. 24–26, 29–30, and comes to the conclusion that by 1975 a maximum import of 50 million tons, mostly from the United States, is probable.

[15]*Nuclear Energy and the Production of Electric Power in Europe, op. cit.*, p. 18. A recent communication from M. Sevette, Chief, Electric Power Section, ECE, UN, states: "For France the figure includes coke and all other processed fuels imported from all sources. There is, however, a small compensatory export."

[16]*Europe's Growing Needs of Energy, op. cit.*, pp. 27–30. For a detailed study of the coal industry in the countries of E.C.S.C. (European Coal and Steel Community—France, The Benelux countries, Western Germany, and Italy), see "The Coal Industry in Western Europe," *Rotterdamsche Bank, N.V.* No. 12 (June, 1956), pp. 5–49.

[17]*Relationship between Coal and Black Oils in the West European Fuel Market, op. cit.*, p. 50; also *The Coal Industry in Western Europe, op. cit.*, p. 23.

The picture is somewhat brighter in lignite with a yearly increased production in the O.E.E.C. area estimated at approximately 2.5 percent per annum until 1960 and a maintenance of this output.[18]

Coal Versus Oil and Natural Gas

It is generally agreed then that the over-all coal output is unlikely to increase very much. Rising costs may even reduce present production levels. On the other hand, consumption of energy in Western Europe increased between 1937 and 1953 by roughly 23.5 percent, but only 6 percent was supplied by coal and lignite while roughly 11 percent came from oil and the remainder came from hydro power.[19] Most of the oil consumed in the O.E.E.C. countries is imported from the Middle East[20] but the upward trend of prices and the unstable political situation is a great concern.[21] On the other hand, significant discoveries in Austria, Italy, Germany, Hungary, The Netherlands, France, and Yugoslavia have already or will in the near future improve the energy balance of individual countries. Some countries, such as Austria, Rumania and Hungary,[22] even have exportable surpluses. But all of Europe's production together covers less than one-fifth of its consumption and it is hardly thought that this percentage will change much, especially in view of the small known reserves.

The question then arises for the reasons for this rapid increase in the use of oil in European—more proven in Western European—energy needs. These reasons are in many ways obvious, but the priority at a given time is difficult to discern. Briefly they are: (1) the general fuel shortage in the postwar years, (2) government policies, and (3) technical and economic advantages. Little has to be added to the reasons for the fuel shortage in the postwar years. This fuel shortage and the relative ease with which crude oil and oil can be transported, together with the encouragement of various governments for the building of refineries, and the willingness of British and United States oil companies to finance both purchases and a large-scale building program, greatly contributed toward the increased importance of oil in the Western European energy balance. When coal production became insufficient to meet the ever-increasing demands, and hydro power was not available or was insufficient, it was only natural that the economic and technical qualities of oil (often including more dependable delivery) should appeal to the consumer. It is obvious then that recent discoveries within Europe, plus large-scale imports of crude oil, will have to supply the increased

TABLE 3. — RESERVES AND PRODUCTION OF CRUDE OIL IN O.E.E.C. COUNTRIES[1]

Country	Proved reserves as of mid-1955 (million tons)	Production 1955 (million tons)	Life in years at present rate of production
Austria	34	3.7	9
France	11	0.9	12
Federal Republic of Germany	48	3.1	16
Italy[2]	16	0.2	80
Netherlands	13	1.0	13
Turkey	11	0.2	55
OEEC Total	133	9.1	15

[1]*Source: World Oil*, August 15, 1955.

[2]Production in the newly discovered fields, which account for the major part of the proved reserves, has not yet started.

[18]Attention is called to the fact that due to the low calorific value of lignite in its crude state its use is much more confined to the immediate hinterland of its mining. Lignite is either consumed in nearby power plants or made into briquettes. See lignite production and forecast in Heuvel, *op. cit.*, pp. 36–37, and *Europe's Growing Needs of Energy*, *op. cit.*, p. 23.

[19]*Relationship between Coal and Black Oils in the West European Fuel Market*, *op. cit.*, p. 3.

[20]Imports of crude oil from the Middle East amounted to 93 percent of the total imports in 1953. See *ibid.*, pp. 60–62. Western European refinery capacity has greatly increased and now the capacity has reached 800 million barrels, an amount sufficient to supply all requirements. For a detailed breakdown of the source of these imports and the changes since 1932 see *ibid.*, p. 58. Oil imports to Europe supply 90 percent of present demands.

[21]United Nations, Economic Commission for Europe, *The Price of Oil in Western Europe*, E/ECE/205 (Geneva, 1955).

[22]Export of oil from Eastern European countries, such as Rumania and Hungary, is made possible by the low consumption, which is estimated at only approximately 12 percent of the total European consumption. Comparable figures for coal were about 16 percent of all coal used in Europe. See *Relationship between Coal and Black Oils in the West European Fuel Market*, *op. cit.*, p. 56.

energy needs for the time being[23] (see Table 3). The competitive position of oil will depend upon the costs of coal, hydro, and nuclear power in the years to come. At present oil appears to be plentiful but it is expensive fuel to use in power stations. Kay, in a recent study, strongly urges that it "should be reserved increasingly for use where a liquid fuel is essential."[24]

Something should be said about the use of natural gas. Today its use is so minor that most statistics do not even mention its percentage. Recent discoveries, however, especially in Italy (Lombardy), Southern France (Lacy), Austria (Lower Austria), Yugoslavia (Banat and Slavonia), The Netherlands and The Federal Republic of Germany, hold hope for larger reserves and utilization. Discoveries, especially in Western Europe, have been very encouraging and pipe lines are now being laid in various parts of Europe. It is hoped that this low-cost form of energy can make a more important contribution to the energy supply of Europe. At the moment the whole annual production corresponds only to approximately 12.6 million metric tons of coal (see also Table 1).[25]

Hydro Power

Europe generally has two hydro power regions—the Alpine region and the Scottish-Scandinavian Highland region. Between these two hydro regions are the important coal and lignite fields of Britain, France, Belgium, Germany, Czechoslovakia, and Poland. South of the Alpine hydro region is a thermal region which includes most of Spain, southern France, parts of Italy and Greece. Coal generally must be imported in this region.

Hydro plants, unlike thermal plants, are confined to certain sites depending on the topography and climate and regardless of consumer concentration.[26] Therefore the length of the transmission lines which carry power to the consuming centers is an important factor in the consideration of costs. Thermal plants[27] also are often built close to the raw energy—coal. This is due to the high transportation cost of lignite and the practice of producing electricity at the coal mine and the technical progress of transmitting power to far-away consuming regions. Production of thermal power at the consuming regions is made possible by the high cost of power transmission versus the smaller cost of transporting coal to the consuming regions. This competitiveness of coal reaches most of Central Europe and far into its southern parts. Navigable rivers and the willingness of the mines to export coal instead of power facilitates this exchange.[28]

The whole question of Europe's hydro power is closely related to the "hinterland concepts,"[29] the relative scale of consumption, and hydro resources. The problems

[23] *Resources for Freedom, op. cit.*, and van den Heuvel, *op. cit.*, estimate a five to seven percent increase per annum in the consumption of oil in Western Europe, even though the rapid increase between 1948 and 1956 (consumption doubled) is not expected to repeat itself. For a detailed discussion of the position and prospects of the oil industry in the O.E.E.C. countries, see *Europe's Growing Needs of Energy, op. cit.*, pp. 30–33.

[24] J. M. Kay, "The Role of Nuclear Energy in Relation to Other Methods of Electricity Generation," *International Conference*, Vol. I, pp. 357–361.

[25] For a discussion of the economic aspects of natural gas see Louis Armand, *Some Aspects of the European Energy Problem* (Paris: O.E.E.C., 1955), pp. 36–38. The figure quoted includes methane gas from coal mines and was supplied by the Economic Commission for Europe, June 1956. For the future use of natural gas in the O.E.E.C. countries see Heuvel, *op. cit.*, p. 26, and *Europe's Growing Needs of Energy, op. cit.*, pp. 36–38. The often publicized pipeline from the natural gas–petroleum fields of the Middle East across Turkey, Bulgaria, and Yugoslavia to Central and Western Europe is questionable politically.

[26] Generally speaking, we recognize two hydroelectric generating sources: (1) run-of-river and (2) storage. Power output in the first depends on the flow of the river. Power out of storage plants is limited only by the storage capacity. For a discussion of capacity, plant and load factors, see Eric W. Zimmerman, *World Resources and Industries* (rev. ed.; New York: Harper & Bros., 1951), chap. 37.

[27] With coal consumption making up as much as 50 percent of the costs—which is generally higher than in the United States—much research and considerable progress has been made in reducing coal consumption per kwh in thermal power stations.

[28] Ernst Kaussmann, "Standortprobleme der europaeischen Atomkraftwirtschaft," *Mitteilungen der List Gesellschaft, E.V.* Nr. 2 (February 15, 1956), p. 29. Those industries using a large amount of energy naturally try to locate near the cheapest available raw energy.

[29] It should be noted here that the availability of hydro power is not necessarily related to the seasonal distribution of consumption. For this reason it is

TABLE 4. — EXTENT TO WHICH EUROPEAN HYDROELECTRIC POTENTIAL WAS HARNESSED ON 1 JANUARY 1955[1]

(COUNTRIES ARE LISTED IN ASCENDING ORDER OF THE DATE IN COLUMN 6)

Country[2]	Economic potential still to be harnessed (10^6 kWh/year)	Mean hydroelectric production in 1954		Periods for which hydro resources could meet the growth in consumption[3]	
		As a percentage of total hydro resources	As a percentage of total production of electric power in 1954	Number of years	Year in which the potential will be fully absorbed
1	2	3	4	5	6
Netherlands	—	—	—	—	—
Saar	—	80	1	—	—
Ireland	300	71	51	5	1959
Denmark	20	60	1	7	1961
Western Germany	6,150	62	15	7	1961
Italy	24,200	56	87	9	1963
France	35,590	40	53	13	1967
Finland	12,000	31	92	13	1967
Sweden	56,400	30	99	19	1973
Eastern Germany	1,480	26[4]	2[4]	19	1973
Switzerland	15,200	49	112	20	1974
Spain	23,650	25[4]	83[4]	20	1974
United Kingdom	7,160	24	3	21	1975
Norway	78,110	22	100	22	1976
Portugal	11,550	11	87	24	1978
Belgium	395	28	1	25	1979
Poland	4,600	16[4]	6[4]	26	1980
Czechoslovakia	10,700	14[4]	13[4]	28	1982
Bulgaria	5,150	14[4]	47[4]	28	1982
Austria	33,000	18	73	33	1987
Luxembourg[5]	60	6	—	40	1994
Greece	5,070	1[4]	3	46[4]	2000[6]
Hungary	1,450	3[4]	1[4]	49	2003
Yugoslavia	64,690	3	53	54	2008
Romania	26,670	1[4]	9[4]	63	2017
Turkey	89,900	—	6	101	2055
Total	513,495	23	38	21	1975

[1]*Source:* Economic Commission for Europe, United Nations, *Nuclear Energy and the Production of Electric Power in Europe*, E/ECE/EP/181 (Geneva: February 1956), p. 27.

[2]The countries italicized are those which have indicated rates of increase for their future consumption.

[3]The following basic assumptions were made by the Economic Commission for Europe when calculating these figures: "Hydro power production accounts for about 40% of Europe's output of electric power, and hydro power resources cannot be used to produce any other form of energy. The upper limits of these resources have been estimated for each country on two assumptions, namely: that the present ratio of thermal to hydro power production will remain constant in the future; and that electric power consumption will increase at the rates indicated by the various countries. Where a country has supplied no data, it has been assumed that consumption will double itself every ten years."

[4]Estimate.

[5]Very negligible use of hydropower gives the appearance of a favorable showing for the future.

[6]Taken from the "Report of the Atomic Energy Commission of Greece on the Energy Needs and Sources in Greece: Heat and Power Requirements during the Next Forty Years" (A/CONF. 8/P/1102).

necessary to refer to an average, high-water night and winter-day hinterland. The location of these hinterlands determines transmission needs and influences costs per kwh. For a detailed discussion of hinterland concepts see P. Ailleret, "The Integrated Power System and the Possibilities for the Development of European Power Grid," in Vol. III, ***Fuel and Energy Resources*** of the United Nations, Department of Economic Affairs, *Proceedings of the United Nations Scientific Conference on the Conservation and Utilization of Resources*, 1949 (New York: United Nations, 1951), pp. 250–255.

today can be envisaged as being twofold:[30] (1) the supply problem at dry periods which makes necessary interconnections with the thermal network, and (2) the building of additional power stations—either run-of-the-river or with large storage capacities in those countries still having surplus power sites[31] able to produce power at competitive low costs. The problem of available sites is a most serious one, as can easily be seen from Table 4. With the exception of Austria and some countries in Southeastern Europe (due to low consumption) the potential of all other countries of Europe will be fully absorbed in less than 30 years. Twenty-five percent of Europe's economic potential of hydro power has already been developed and many less economical sites are now being developed. This problem is especially serious in the more industrialized countries of Western Europe where all potential sites will be developed in less than 20 years.

Coal and hydro power—the latter even under accelerated expansion—will be unable to meet Europe's increased needs. Hydro power now supplies 9.9 percent of Europe's needs. This supply will be increased at an annual cumulative trend of approximately 64 per cent at the most,[32] a rate insufficient to change Europe's energy supply balance materially.

The only opportunity for greater utilization of hydro power is intra-European cooperation, as expressed in the exchange of electric power across national boundaries. The future of such developments has been explored in several studies prepared by the Electric Power Committee of the United Nations and the O.E.E.C., and has been reported in a recent study by the author.[33] At the moment at least, international exchange is very limited, amounting to between 1.3 and 1.6 percent of the total electric power exported for all of Europe between 1937 and 1954.[34] While this international exchange seems small, it alleviates shortages which occur due to peak consumption or other circumstances from time to time in various regions.

TABLE 5. — ANNUAL RATES OF INCREASE OF ENERGY CONSUMPTION IN EUROPE (NOT INCLUDING THE USSR) 1937 TO 1953, 1949 TO 1953[1]
(PERCENT)

Energy source	Period	
	1937 to 1953	1949 to 1953
Solid fuels	0.7	3.4
Liquid fuels	5.1	11.8
Natural gas	5.2	20.0
Hydro-electric power	5.0	11.0
Total electric power	5.2	9.3
Total energy from commercial resources	1.2	4.8

[1]*Source:* Economic Commission for Europe, United Nations, *Annual Rates of Increase of Energy Consumption In Europe*, E/ECE/EP/181 (Geneva: February 1956), p. 25.

PRESENT ENERGY BALANCE

Because electric power production is one of the main reasons for developing nuclear energy, the present energy balance and the various factors influencing its development during the next ten to twenty years assume a special importance. From the foregoing discussions certain facts peculiar to the European energy picture have developed clearly. They are summarized here:

(1) Energy consumption in Europe has increased at an accelerated rate as may be seen in Table 5. The mean rate of increase for the next 20 to 40 years has been estimated

[30]United Nations, Economic Commission for Europe, Committee on Electric Power, *Hydro-electric Potential of Europe, Its Gross, Technical and Economic Limits*, E/ECE/EP/131 (Geneva, 1953). For example, Switzerland helped finance a French thermal power plant (Dieppedalle) in return for winter power. See also other papers presented under "The Integrated Power System," cited in fn. 29 above.

[31]A recent detailed study of the Alpine storage lakes, Obering H. Link, "Die Speicherseen der Alpen," *Schweizerische Wasserwirtschaftsverband, Verbandschrift Nr. 31* (Zeurich, 1953).

[32]Van den Heuvel, *op. cit.*, p. 25. The O.E.E.C. in its most recent study, *Europe's Growing Needs of Energy*, *op. cit.*, p. 34, estimates a rise of 7 percent per annum in the demand for electricity in the member countries. During 1955, 60 percent of the electricity consumed was produced in thermal and 40 percent in hydro stations.

[33]Hoffman, *op. cit.*, pp. 165–176.

[34]*Nuclear Energy and the Production of Electric Power in Europe*, *op. cit.*, p. 20; United Nations, Economic Commission for Europe, Committee on Electric Power, *The Electric Power Situation in Europe in 1954*, E/ECE/EP/173, Rev. 1 (Geneva, 1956). Austria exports over 13 percent of her power and is the largest exporter in Europe. Latest O.E.E.C. figures give the percentage for power exchanged as "just under 3 percent of the total consumption of the interconnected countries."

TABLE 6. — ESTIMATED AVERAGE ANNUAL RATE OF INCREASE IN FUTURE ENERGY CONSUMPTION IN SELECTED COUNTRIES[1] (PERCENT)

Country	Mean rate of increase, per cent		Period
	Total energy	Electric power	
Austria	2.5	5.3	1950–1980
Belgium	1.7	5.3	1955–1980
Denmark	2.5	7.5	1955–1975
	1.8	3.5	1975–2000
Finland		11.0	1954–1960
	4.2	8.0	1960–1970
Greece		7.6	1955–1975
		2.9	1975–2000
Germany (Fed. Republic)	1.7		1954–1970
Italy		7.0	1955–1960
		6.0	1960–1970
Netherlands	2.0	7.2	1954–1970
	1.7		1954–2000
Portugal		10.5	1954–1960
		8.5	1960–1970
Romania	6.3[2]	9.7[2]	1960–1970
	4.5[2]	6.7[2]	1970–2000
Sweden		6.5	1954–2000
Switzerland	1.4	3.6	1951–1975
	1.3	2.0	1951–2000
United Kingdom	2.0[3]		1954–1975
Yugoslavia		12.0	1954–1960
		7.0	1960–1975
		6.0	1975–2000
	3.6		1954–2000

[1]Compiled from Department of Economic and Social Affairs, United Nations, "Contribution of Nuclear Energy to Future World Power Needs," *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy*, Vol. 1, p. 89, and Economic Commission for Europe, United Nations, *Nuclear Energy and the Production of Electric Power in Europe*, E/ECE/EP/181 (Geneva, 1956), p. 13.

[2]Official estimate.

[3]Probable figure; maximum possible: 2.8.

from figures compiled by the United Nations. It shows clearly that increased consumption will be the guiding motive of the European energy picture (Table 6).

(2) The coal supply will increase very slowly until 1965, but will remain stable from then on. All additional energy required must be provided by oil, natural gas, hydro power, and nuclear energy. Hydro power's contribution to the European energy balance is expected to increase from the present 9.9 to 16 percent by 1965. Oil consumption in Europe in 1955 was 12 percent of the total energy consumption; in the O.E.E.C. countries it amounted to 17.2 percent. Estimated increases in petroleum contribution range from 18 to 25 percent, in the natural gas supply from 1.4 to 5 percent of the total European consumption by 1975. But all these figures will be affected sharply by the cost of production which in turn will greatly affect the use of nuclear energy in Europe. At the moment all increased energy consumed must be provided by oil and hydro power and to a lesser degree by natural gas. This is especially true for the countries of Western Europe. The future development of the various energy resources in Eastern Europe will greatly depend upon the standard of living and further increases in industrial production.

(3) Interregional movements of energy resources in Europe have declined over the last 20 years. Less than 10 percent of the coal mined is transported beyond a radius of 50 km; coal exports of the three largest surplus areas of Europe—the United Kingdom, Western Germany, and Poland—have declined for reasons discussed earlier. On the other hand, coal imports from overseas have increased. Interregional movements of oil have greatly increased. This results partly from the role oil now plays in European consumption and this in turn is brought about by the greater mobility of this energy resource. The international transfer of electric power across national boundaries is presently of minor importance, even though it is of some regional importance, for example, between Austria and Germany. Several schemes for increased movements are now under discussion which could materially increase this movement in the future.[35]

(4) Power policies in individual European countries vary greatly and economic produc-

[35]Hoffman, *op. cit.*, pp. 169–176, and United Nations, Economic Commission for Europe, Committee on Electric Power, *Transfer of Electric Power Across European Frontiers*, E/ECE/EP/128 (Geneva, 1952). Among the many general and specific papers dealing with the international transfer of power presented at the recent 5th World Power Conference in Vienna, Austria, the following are mentioned: Filippo Carati, "Die internationale energiewirtschaftliche Nutzung des Einzugsgebietes des Oberen Inn," conference proof, *5th World Power Conference*, 1956, 118 0/1; Guenther Oberdorfer, "Oesterreich im elektrischen Verbundbetrieb Europas," conference proof, *5th World Power Conference*, 1956, 8 N/3; and Vladimir Slebinger, "Possibilités d'Intégration des Forces hydrauliques des Dinarides et des Alpes Orientales," conference proof, *5th World Power Conference*, 1956, 213 0/6.

tion often must make way for conflicting national interests of self-sufficiency. The energy balance of a country is usually given on a national basis, but often it might be improved if its focus would be intra-European instead of narrowly national. Such a policy not only would reduce costs of energy production, but would greatly increase the economic utilization of all of Europe's energy resources. The joint development of the hydro potential—one of the few remaining underdeveloped conventional energy resources in Europe—e.g. Inter Alpen Project, Yugoslavian Schemes,[36] will greatly contribute toward a more economic and efficient use of Europe's limited natural resources.

Present shortages, increased costs of coal products, and the utilization in the near future of all economically available hydro power will force Europe to rely more and more upon importing liquid fuel, and the national economies will depend upon a resource owned and controlled largely by non-European sources. Increased costs in supplying Europe's markets may easily affect increased consumption. It therefore becomes clear that all of Europe has a special interest and concern in the future development of a new, competitive energy source — the energy of nuclear power.

THE ECONOMIC GEOGRAPHY OF NUCLEAR POWER

An analysis of the present European energy situation has shown that before long the energy from nuclear sources will become essential to many countries.[37] European needs cannot be satisfied by conventional energy sources alone if electric power demands continue to double every 10 years.[38] What place the energy produced from nuclear sources will take in Europe and how important it will be will depend upon the requirements of individual countries—and these requirements may vary greatly from country to country—and on how available and adaptable energy from fissionable material[39] is in comparison with energy from all other sources. While costs obviously will play an important part in the competitive position between conventional and nuclear fuels, for many countries the need of obtaining an additional source of energy will outweigh higher costs.[40]

In general the role of nuclear power is of varied interest to the geographer. Not only does it affect basic relationships in the distribution and use of resources, for example, availability of raw materials, preferable sites for reactors, possible redistribution of industries, relationship between nuclear energy and conventional energy, etc., but it also raises questions in connection with joint undertakings, such as international control of nuclear

[36]United Nations, Economic Commission for Europe, Committee on Electric Power, "Brief Account of 'Interalpen' Activities During 1954," EP/77 (Geneva, 1955); United Nations, Economic Commission for Europe, *Prospects of Exporting Electric Power from Yugoslavia*, E/ECE/192 and E/ECE/EP/154 (Geneva, 1955).

[37]Four recent papers evaluate the importance of nuclear energy to the future energy supply of Europe: Working Party on Nuclear Energy, O.E.E.C., *Possibilities of Action in the Field of Nuclear Energy* (Paris: O.E.E.C., 1956); *Nuclear Energy and the Production of Electric Power in Europe*, *op. cit.*; Louis Armand, "Atomic Energy and the Future of Europe," *Foreign Affairs*, Vol. XXXIV (July 1956), pp. 654–665; *Europe's Growing Needs of Energy*, *op. cit.*

[38]For the O.E.E.C. countries a detailed study has been published in *Europe's Growing Needs of Energy*, *op. cit.*, pp. 65–73, forecasting requirements and supply in 1960 and 1975. See also Harry I. Miller and F. Douglas Campbell, *Economic Aspects of Electric Power Production in Selected Countries*, Office of Industrial Resources, International Cooperation Administration (Washington, D.C., July, 1955).

[39]Fissionable materials, U^{235}, and Pu^{239} and others, are used in producing nuclear energy. It is possible for most light nuclei to fuse together, releasing radiation or excess nucleons of high energy, and for most heavy nuclei to burst apart, forming two fragments, each of which is more tightly bound than the original heavy nucleus. The first process is referred to as *fusion* and the second as *fission*. Although these processes are energetically possible in many cases, they do not naturally occur because the charged protons in any other nucleus will electrically repel the charged protons in any other nucleus; hence nuclei are generally held apart by the electric charges between them. If two nuclei do get very close together, the proton repulsive forces are overcome by a specific nuclear force which is attractive, and nuclear reactions including *fusion* may take place.

[40]W. Kenneth Davis, "Status of Nuclear Power Technology," private distribution, *5th World Power Conference*, 1956. For an evaluation of the future place of nuclear energy see Eugene Ayres and Charles A. Scarlott, *Energy Sources—The Wealth of the World* (New York: McGraw-Hill Co., 1952), pp. 168 ff.; and K. M. Mayer, "The Economic Potential of Nuclear Power," *International Conference*, Vol. I, pp. 400–408.

fuels, erection of certain plants in extraterritorial locations, joint training of technicians, research, financing, and control of production. The objective of the following discussions is an analysis of some of the problems basic to the production of nuclear power.

Raw Materials for Nuclear Fuels

The basic raw materials for the production of nuclear energy are the minerals uranium and thorium.[41] In the United States uranium and thorium are also referred to as "source materials."[42] Uranium today is the primary source of nuclear fuel. For the production of nuclear power pure uranium or uranium compounds must be used. However, two other fuels can be prepared by using pure uranium.[43] Also, thorium can be converted to become a second nuclear fuel material—U^{233}.[44]

Pure uranium, the most important raw material and the main source of nuclear power fuel, occurs all over the world in concentrated deposits, such as uraninite,[45] pitchblende, carnotite, but also in many different minerals. Uranium also occurs in low content in many sedimentary formations, such as shale, phosphate rock, and lignite.[46] Pitchblende and uraninite contain 50–80 percent uranium, while the percentage is somewhat lower for carnotite, autunite, etc., and is less than 18 percent, for example, in davidite. Most of the uranium-bearing minerals, however, contain only small amounts of uranium, together with other major constituents. Actually only very few minerals can be considered as uranium ore minerals and can be found to form uranium ore deposits of any importance.[47]

[41]For a discussion of these minerals and their occurrences see Robert D. Nininger, *Minerals for Atomic Energy* (New York: D. van Nostrand Co., 1955), pp. 15–18, 25–85.

[42]This term had its origin in the Atomic Energy Act of 1946 (Public Law 585–79th Congress) and is defined as "uranium, thorium, or any other material which is determined by the Commission with the approval of the President, to be peculiarly essential to the production of fissionable materials; but includes ores only if they contain one or more of the foregoing materials in such concentrations as the Commission may by regulation determine from time to time."

[43]All uranium found in nature consists of two isotopes—U^{235} and U^{238}. Indeed, *natural uranium* is about one percent U^{235}, the remainder being U^{238}. Only the U^{235} will undergo the fission process with slow neutrons. The U^{238} which is present will only serve to capture slow neutrons, forming U^{239}, which does not fission. Instead, it is radioactive; some of its neutrons spontaneously turn into protons (causing this nucleus to eject high speed electrons, called Beta-rays), and the result is a new element, called *plutonium*; the isotope of plutonium thus formed is written Pu^{239}. The important fact is that Pu^{239} will undergo fission by slow neutrons, and hence it is possible to make fissionable material from U^{238} by operating a reactor which consists of normal uranium (i.e., the mixed isotopes U^{235} and U^{238}). It is also important to note that the Pu^{239} is chemically different from uranium, and hence this fissionable material may be separated chemically from the rest of the reactor constituents. This process of building up additional fissionable material within an operating reactor is known as *breeding*. For additional technical background information see Henry H. Hausner and Stanley E. Roboff, *Materials for Nuclear Power Reactors* (New York: Reinhold Publishing Corp., 1955).

[44]There are isotopes of the fairly abundant element *thorium* which can be made into fissionable materials by the breeding process. Thorium of mass 232 (written Th^{232}) can be placed in a reactor. It will not undergo fission by slow neutrons, but, like U^{238}, it will absorb them. This produces Th^{233}, which, by a series of radioactive changes similar to those described for U^{239}, will become U^{233}. The element U^{233} will undergo fission by slow neutrons, and hence one may use the breeding principle to convert thorium into a new isotope (U^{233}) which is suitable for producing nuclear power (through slow neutron fission).

[45]Uraninite and pitchblende are varieties of the same mineral.

[46]E. W. Morehouse and Theodore Baumeister, "How Will Atomic Power Affect the Electric Power Industry," *Land Economics*, Vol. XXXI (May, 1955), p. 95, shows a table on world reserves of fossil fuels and uranium and thorium. This table shows that the estimated supply of these two "source materials" is 23 to 25 times that of all estimated reserves of coal, oil, and natural gas. Putnam, *op. cit.*, comes to the same conclusion.

[47]One reason it is so difficult to prospect for uranium is its widespread distribution in small quantities in various rocks. Granite, for example, contains on an average four parts of uranium per million. In a paper by H. Brown and L. T. Silver, "The Possibilities of Securing Long-Range Supplies of Uranium, Thorium and Other Substances from Igneous Rocks," *International Conference*, Vol. VIII (New York: United Nations, 1956), pp. 129–132, the authors come to the conclusion that if all the uranium and thorium could be extracted from one ton of granite and converted into fissionable material, then burned in a nuclear reactor, the energy released would be equal to the energy obtained from burning about 50 tons of coal. Only 25 percent of the uranium and thorium in granite rock is leachable, consequently one ton of granite would produce releasable energy equivalent to 10–15 tons of coal.

TABLE 7. – THE EUROPEAN NUCLEAR ENERGY EFFORT

A. *Membership in International Organizations:*

(i) O.E.E.C.: Austria, Belgium, Denmark, France, Western Germany, Greece, Iceland, Ireland, Italy, The Netherlands, Norway, Luxembourg, Portugal, Sweden, Switzerland, Turkey, United Kingdom

(ii) EURATOM: Belgium, France, Western Germany, Italy, The Netherlands, Luxembourg

B. *Bilateral Agreements between the United States, the U.S.S.R. and different European countries for the exchange of information and raw materials:*

(i) Agreements with the United States:[1] Austria, Belgium, Denmark, France, Western Germany, Greece, Italy, The Netherlands, Norway, Luxembourg, Portugal, Sweden, Switzerland, Turkey, United Kingdom

(ii) Agreements with the U.S.S.R.:[2] Bulgaria, Czechoslovakia, Eastern Germany, Yugoslavia, Hungary, Romania, Poland

C. *Nuclear Facilities in Selected Countries of Western Europe:*

Name of Country	*Reactors*	*Isotope, heavy water*	*Research and training facilities*
Belgium	Research reactor		Mol (north of Brusselles)[3]
France	Marcoules–3[4] Material testing[5]		Saclay–2[3], Grenoble[6] total employment c. 2000
Norway	Oslo[6]	Heavy water–1	Kjeller[3] Oslo[5]–total employment 200
Sweden	Research reactor–2[5]		Stockholm, Royal Institute for Experimental Physics
Switzerland	Research reactor (U.S. gift)		Laboratories of "CERN" near Meyrin, Geneva
United Kingdom	Calder Hall:[7] 1–6 1–in production for national supply Dounreay (North Scotland): fast breeder reactor Capehurst: diffusion plant for U^{235} Sellafield: mfg. of plutonium	Isotope plant	Harwell–3, 6 Risley–design

[1]As of September 1956. Agreements with the United States regarding delivery of U-enriched in the isotope U^{235} and non-restricted information on development, construction and use of research reactors. Some agreements cover only lease of U^{235} enriched to 20 percent to be used in construction of research reactors (France, Norway) and sale of heavy water (Italy, France) and others are more comprehensive (United Kingdom, Belgium).

[2]As of September 1956. U.S.S.R. offered to establish scientific centers for developments in nuclear physics (scientific technical assistant agreements). Agreements included future design and manufacture of 2000-kw nuclear reactors for production of isotopes and cyclotrons for production of protons, deuterons and alpha particles with energy up to 25 megawatt.

[3]Well integrated research center with various operations and training facilities.

[4]Pilot reactor.

[5]Under construction or projected.

[6]Research reactor.

[7]"Calder Hall und das britische Atomkraftwerkprogram," *Neue Zeuricher Zeitung*, October 21, 1956.

Uranium deposits generally are to be found in two major types of deposits:[48] (1) in granite-like igneous rocks or in metamorphic rock of high silica content; pegmatite and vein deposits, with vein deposits of uraninite or pitchblende being the most productive; (2) in flat-lying deposits in sedimentary rocks, which include secondary limestones, asphaltic sandstones, phosphate–limestones of Florida, minerals in sandstones, uraninite or pitchblende in sandstones to mention only a few.

Increased prospecting during the last ten years permits the conclusion that commercial uranium deposits of varied sizes may be found in many different parts of the world, and under different geological conditions, even though many countries in the world have been only partly explored.[49]

The vein deposits of pitchblende are the most important uranium occurrences in the world. The major areas presently under exploitation are Port Radium on Great Bear Lake and the Beaverlodge area of Saskatchewan, both in Canada, the Shinkolobwe Mines of the Belgian Congo close to Northern Rhodesia, and the Erz Gebirge (Iron Mountain) along the Czech–German border in Central Europe. Important deposits in Transvaal and Orange Free State of the Union of South Africa ultimately may be included in this group also. Other vein uranium occurrences are to be found in Australia, France, The United Kingdom, and Portugal. The most important flat-lying deposits are in the Colorado Plateau of the United States, in Sweden, and at Ferghana (Uzbek, SSR) of the USSR.

At the present time uranium mining is being carried on in several places in Europe and prospecting is being pursued at an accelerated pace in nearly every country (see Table 7). The most important occurrences of uranium are in the Erz Gebirge both in Saxony (Eastern Germany) and the Joachimsthal (Tachymov) region of Czechoslovakia. Uranium was mined at one time in Devon and Cornwall, England, the north central part of Portugal, the Urgeirica mine area and along the northern edge of the Massif Central (France) as far west as Limoges. Prospecting and small-scale mining has recently been reported in Sweden, Yugoslavia, Northern Italy, France, and Bulgaria. A brief summary of the more important occurrences follows (Fig. 2).

(1) The Erz Gebirge deposits on the Czech–German border in the Bohemian Massif, all the way from the Joachimsthal in the north to Marienbad in the south. This whole area was important silver mining country in the 16th century long before pitchblende (in the 1850's) and radium (1898) were discovered there. The most valuable veins containing pitchblende mineralization are usually found in greater depths.

(2) The region between Devon and Cornwall in southwestern England has a number of pitchblende veins, together with quartz. Tin, lead, and copper have been mined here since about 1450, but when pitchblende was discovered in the Belgian Congo, mining was discontinued here for a long time. At the present time the best uranium mineralization is found in the copper mines.

(3) Another old uranium producing area is in north central Portugal, an area of about 65 square miles on the western side of the Spanish Meseta, centered around the Urgeirica mines. At an earlier stage of uranium mining the Portuguese mines played a very significant role in the world market. Pitchblende is found only in mines of great depth.

(4) Since 1945 important uranium deposits have been found on the northern edge of the Massif Central in central France. Autunite (near the city of Autun on the northeastern edge of the Massif Central) has been mined for many years, but the discovery of pitchblende below secondary minerals along granite fractures has greatly enhanced the importance of this region. Deposits are similar to those in Portugal.

(5) Small deposits of autunite and torbernite have been found near Bukhova, Bulgaria, about eight miles northwest of Sofia. These are no true vein deposits.

Ores containing thorium are much fewer than those containing uranium and, even though they are distributed rather widely over the world, their concentration is relatively

[48]For detailed information on these locations see Nininger, *op. cit.*, pp. 42–159, and United Nations, "The Natural Occurrence of Uranium and Thorium," *International Conference*, Vol. VI (New York: United Nations, 1956), pp. 5–59.

[49]Jesse C. Johnson, "Nuclear Fuel for the World Power Program," *ibid.*, pp. 60–62. This study includes a brief discussion of future developments.

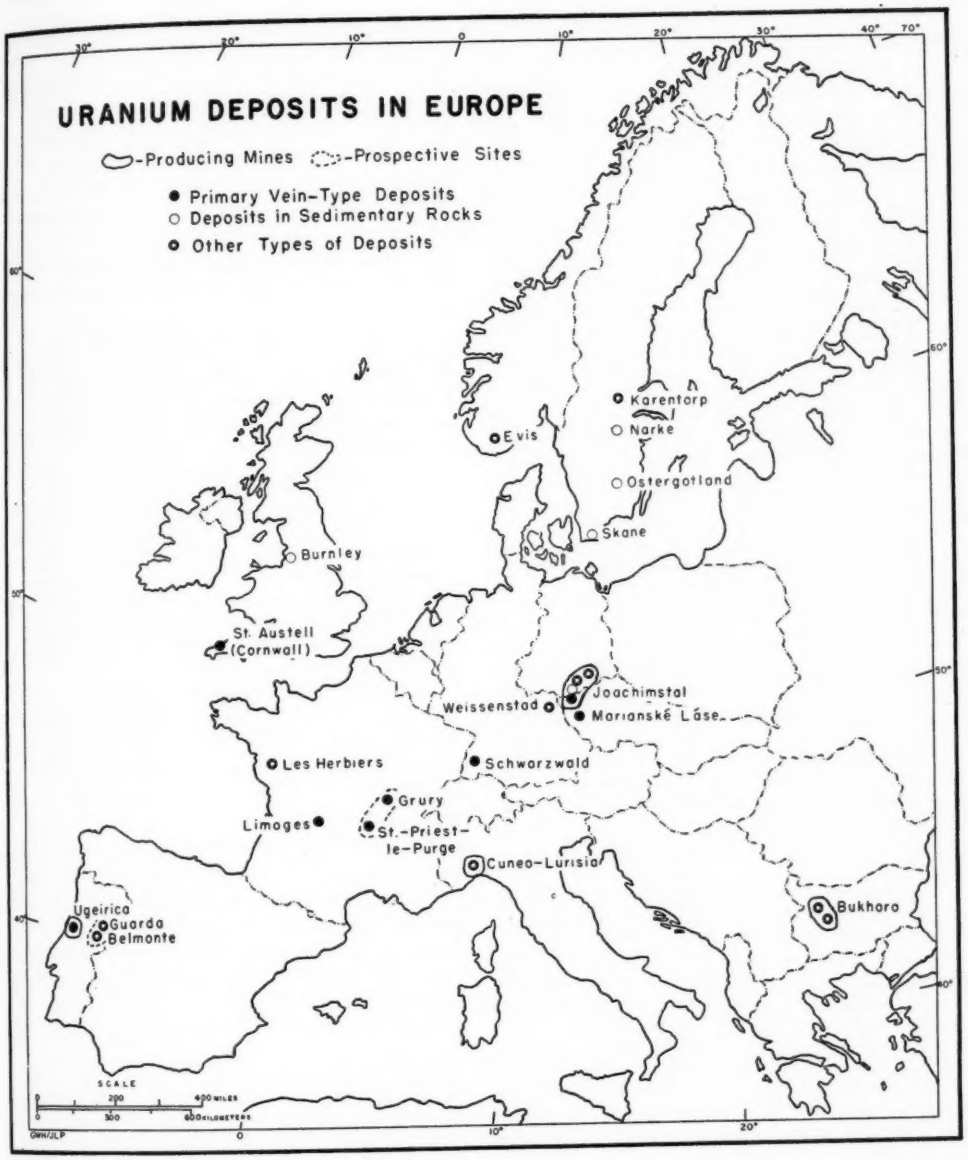

FIGURE 2

low. The only ore mineral of thorium is monazite[50] which occurs as brown crystals in granite, gneiss, and pegmatites; it is found in commercial quantities in sands and gravels (by erosion and weathering processes) bordering rivers and on beaches, close to or in large concentrations of primary host rocks. The largest productions of monazite are found in India and Brazil. Other important deposits are in the Cape Province of South Africa, Madagascar, and the states of Idaho, Cali-

[50]Monazite is phosphate of the rare earths containing 1–15 percent thorium oxide.

fornia, and North Carolina.[51] No deposits are reported anywhere in Europe.

On the whole, prospecting for uranium and thorium has moved along rather rapidly and supplies are increasing. The conclusion can be reached that raw materials for nuclear fuels will be available in sufficient amounts to cover all expected increase during the years, even though some of the raw materials may need to be imported from overseas areas. With scientists already working on the problem of increasing the amount of energy which can be extracted from each ton of uranium and thorium, and making use of the "breeder principle" it should be possible to extract a large amount of the fissionable energy from uranium.[52] Obviously the problem of raw material supply for nuclear fuels is becoming of minor importance in the production of nuclear power.

Locational Problems of Nuclear Power Plants

The Reactor

Power production reactors are being designed and constructed in large numbers. Pilot models are now in operation in various countries of Europe.[53] The need for nuclear power being more urgent in certain European countries where financial means are more limited, the reactor program is confined to a few models. The problem of reactors is that "the design will have to represent a compromise between what is believed to be best for power generation and what is believed to be best for the efficient conversion of U^{238} to plutonium. We must assume that a satisfactory compromise can be found."[54] Hausner and Roboff state the future problem as follows:

> The plutonium-producing reactors, that is reactors which were designed and built for the sole purpose of converting uranium 238 into plutonium, operate at relatively low temperatures. No serious attempt has been made to efficiently utilize the heat which is produced as a by-product. Power reactors, on the other hand, are designed primarily to effect efficient recovery of the energy of nuclear fission, in the form of heat, and at the highest possible temperatures. High temperatures are desired because of the higher yields of "usable power" which are possible at high temperatures. Some of the power reactors will also attempt to make efficient use of their by-product, plutonium, either as a direct fuel or as a product for military purposes.[55]

Scientists and engineers generally agree that power reactors are still in the experimental stage. Many technical problems are still awaiting their solution and design in the years to come may differ, according to Sir John Cockcroft, as much as the Model T Ford and our present cars. Several basic problems have not been completely solved and are considered in need of further investigation. Some of the more important problems are stated here: (1) the very dangerous radiation produced by reactors so that a thick protective shield must surround them, the weight of which is considerable;[56] (2) the

[51] For a more detailed discussion of thorium metals see Nininger, *op. cit.*, pp. 87–100, Hausner and Roboff, *op. cit.*, pp. 99–103, and Morris A. Steinberg, "Processes for Thorium Recovery," paper presented at Atomic Industrial Forum, Inc., September 1955, pp. 415–429.

[52] Several papers have now been published discussing the possibility of recycling and breeding which may ultimately make one ton of uranium do the work of a million tons of coal. It is generally estimated that one pound of uranium metal, the size of a one-inch cube, is equivalent energywise to about 1,300 tons of average grade bituminous coal.

[53] For a summary of the various European efforts see O.E.E.C. and E.C.E. United Nations Studies. In addition, for the program in the United Kingdom see John Cockcroft, "The Nuclear Power Program in the United Kingdom," paper presented at Atomic Industrial Forum, Inc., September 1955, pp. 505–508. For a summary of the United States reactor program see James A. Lane, "Economics of Nuclear Power," *Research and Engineering*, October–November 1955, pp. 22–27; Delbert M. Lepke, "The Facts of Atomic Power Development: Some Aspects of Nuclear Power Economics," *Law and Contemporary Problems*, Vol. XXI (Winter, 1956), pp. 3–13; and Morehouse and Baumeister, *op. cit.*, pp. 97–100; also the brief and clear summary of reactor concepts by Davis, *op. cit.*, pp. 17–28.

United States efforts are directed toward the best possible reactor and for this reason a large number of prototypes are being tried; the United Kingdom on the other hand is concentrating on a simple type which will permit an early mass production (natural uranium and graphite). This difference in approach represents a fundamental difference of policy, and there is evidently a feeling among some British atomic scientists that "a big section of American research effort into reactor design is a waste of time," according to an article in the *London Economist*, June 2, 1956, pp. 913–915.

[54] Ayres and Scarlott, *op. cit.*, p. 172.

[55] Hausner and Roboff, *op. cit.*, pp. 4–5.

[56] *Ibid.*, pp. 178–188; radiation on the other hand can be used to transform many products placed in the reactor into useful isotopes.

disposal of radioactive waste;[57] (3) availability of good reactor materials,[58] and (4) the breeding of fuel.

In spite of some of the problems awaiting solution, nuclear reactors are in operation. The British Atomic Energy Authority announced recently that the first two atomic piles are in operation and electricity will be generated shortly. Their full capacity will reach 50,000 to 70,000 kw.[59] Other European countries have experimental plants in operation or under construction (Table 7).

Steam is made in a boiler from heat produced in a reactor. This boiler differs from an ordinary boiler, but one of the most important differences is the low consumption of nuclear fuel. Three to four kg of highly "enriched" fuel[60] are sufficient for smaller experimental reactors; several hundred tons of natural uranium for larger reactors, e.g., Marcoule in France or Calder Hall in the United Kingdom. Generally speaking, net consumption is estimated to be 150 kg of fissile material per year for a nuclear generating station with a capacity of 100,000 kw.

The steam thus derived propels conventional steam turbines which rotate the generator and produce electricity, transporting it to the conventional station. But many parts of the boiler, the equipment of the power plant, the transmission and distribution system are the same as our present facilities.[61]

Locational Theories

A recent report published by the O.E.E.C. made the following statement in discussing the future of atomic energy:

> One of the more important features of atomic energy is that it enables power to be produced wherever it is wanted and at a cost independent of the precise locality, all other considerations being equal. Thus the development of atomic energy may profoundly alter economic geography because hitherto, to ensure power supplies, it has been necessary to concentrate large industrial concerns around particular natural sites: coalfields, large-scale hydro schemes, etc. In future things may be quite different. The power will be produced where needed at practically no additional cost because, contrary to what happens for other forms of energy, the cost of transporting fissile ("fissionable" is used in the U.S.) materials will be negligible.[62]

Earlier it was explained that only parts of the present energy producing plant will have to be changed and that once heat is produced nuclear power follows the same laws as conventional power. What, then, are the new installations needed and what are their relationships to the nuclear power plants?

The first mechanical process necessary after the ore is mined is to concentrate the uranium-bearing minerals by crushing, magnetic separation, floating, etc., depending upon the type of the ore. The second step is the physi-

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[57] *Ibid.*, pp. 188–192, stresses that the disposal of this highly dangerous waste depends on "the kind of waste and its activity level, as well as on the location of the respective atomic energy installation."

[58] *Ibid.*, pp. 56–87, and Ayres and Scarlott, *op. cit.*, p. 173, stress that the proper material and the problem of radioactive waste disposal at the moment are the major limiting factors and must be solved before any efficient nuclear power plant can be put into operation.

[59] "Atom Power Unit Opens in Britain," New York *Times*, May 24, 1956; also, "Britain in the Atomic Age," *Labour and Industry in Britain*, Vol. XIV (June, 1956), pp. 62–67.

[60] By various processes one may concentrate U^{235} (or Pu^{239} or Th^{233}), and this may be added to a normal reactor. Such a reactor would then be operating with *enriched* fissionable material, and its size could be reduced without stopping the necessary chain reaction. At present, most reactors operate with enriched fuel: they produce a large amount of heat per unit volume, and their size may be quite small. The installations where uranium can be enriched are known as "isotope separation plants." *Possibilities of Action*, *op. cit.*, Annex IV, pp. 51–55, briefly describes the operations of an isotope separation plant. See also *ibid.*, p. 17.

[61] P. Ailleret and P. Taranger, "Integration of Nuclear Power among the Means of Energy Production," *International Conference*, Vol. I, pp. 354–356.

[62] Armand, *Some Aspects of the European Energy Problem*, *op. cit.*, p. 30. Spedding, *op. cit.*, pp. 1–2, takes exception to the many published general statements that "fuel for nuclear power plants" is of negligible cost. He points out that such fuel cost can be brought below fuel cost in a conventional power plant, but that this is yet to be achieved and commercially tested. He further states that "fuel costs have to be calculated, not on the basis of introducing a certain quantity of fissionable material into the reactor, but on the basis of introducing a certain quantity which will be consumed in producing useful heat. It is necessary, therefore, to add the costs of preparing the fuel element and the cost of extracting and disposing of the waste materials to the cost of the original fissionable material. These costs can be, and frequently are, quite high, and while they can be offset to some degree by by-product utilization, it is very easy, with poor design of the reactor, to have them mount up so high that the nuclear fuel costs considerably more than conventional fuel."

cal or chemical concentration and the purification of the uranium compound. After a series of chemical operations black oxide is put into the form in which it will be used, usually in the form of metal cylinders or rods. These steps are completed near the mining areas. Because concentrates are not bulky and are easily transported, costs for moving the raw materials play a minor role. The important thing for nuclear production is an assurance of a guaranteed supply of fuel for those countries lacking the new raw materials. But due to the small quantities needed, storage precipitates no problem.

The isotope separation plant—the physical separation of U^{235} and U^{238} to acquire "enriched uranium" necessary to operate certain reactors—is of great importance. Because not every country needs such a separation plant, the erection and operation of which is very costly, intra-European cooperation may be most helpful. Great Britain is the only country in Europe at the moment which has an isotope separation plant. The location of such a plant will greatly depend upon whether joint action is possible and on a number of economic, political, and strategic considerations. The possibility of some installations in extraterritorial areas also is under discussion.[63]

Another special plant is one producing heavy water. This is important in certain types of reactors as a moderator for the slowing down of fast neutrons.[64] Norway and to a lesser degree France have facilities for this process. Again, only a small quantity is needed and the location of these plants does not raise any problems. Intra-European action is contemplated here too.

Special installations are also needed for the processing of "irradiated" fuel.[65] The disposal of the radioactive waste poses numerous locational problems. Several methods are now in use, but considering the intensive land use and high population density in most European countries, the location of the disposed waste may ultimately need joint European action. At the moment radioactive waste can either be disposed of on land—near the nuclear power plant, stored in underground tanks, or buried at specific sites, for example, inside a mountain—or in the sea, direct in the ocean or by burying concrete containers on the ocean floor.

While crushing, concentration, purification, and the heavy water plants are located away from the reactor, the work of the isotope separation plant could be coordinated with a reactor in the production of power. Obviously, there will be only a few separation plants and their sites must be carefully chosen. The processing facilities for "spent fuel" must be located close to a reactor; otherwise the problem of transporting this highly radioactive fuel may entail considerable added costs. Some of the components of "spent fuel," after chemical separation, are used as valuable by-products of reactor operations.[66]

From earlier discussion of the reactor and its function, it can be seen that one of the important differences from conventional boilers is its great flexibility as to location. The location of nuclear power plants much closer to maximum load centers (consuming centers) is possible because they are independent of raw energy location, fuels can easily be transported, long transmission lines are unnecessary, and there is little need for storage facilities.

To understand the locational problems of

[63] *Possibilities of Action . . ., op. cit.*, pp. 33–35, and also by members of the Coal and Steel Community for "Euratom."

[64] Three isotopes of hydrogen are known, H^1, H^2, and H^3. H^2 and H^3 are sometimes referred to as *deuterium* and *tritium*, respectively. H^2 exists in normal hyrogen, and it is relatively cheap to produce almost pure H^2 by separating it from H^1. The H^2 is conveniently kept as *heavy water*, which would be written as H_2^2O. It is also practical to produce fairly large quantities of H^3—this was presumably the main purpose of the huge Savannah River plant built by the U.S. Government. The H^3 does not exist appreciably in nature, but it can be made by placing Li^6 in a nuclear reactor. The Li^6 will absorb neutrons and split into helium and H^3. For a detailed description of this process and its importance see Hausner and Roboff, *op. cit.*, pp. 135–138.

[65] When this highly radioactive fuel is treated chemically, one of its fractions becomes radioactive waste (similar to ash of conventional fuel). For a detailed technical discussion see Hausner and Roboff, *op. cit.*, pp. 188–192.

[66] Such as radioactive isotopes, secondary fuels (Pu^{233} and U^{233}) or primary fuel with reduced fissionable materials.

nuclear power plants, certain basic factors must be considered:[67]

(1) Nuclear power plants can be placed in any consuming area, but their full utilization is essential; otherwise their advantage of cost reduction through savings in transmission lines for surplus power would be eliminated. Power plants in sizes below 200 MW are therefore essential for Europe, even though larger units will be used at some of the greater industrial concentrations, for example, Northern France, the British Midlands, and the Vienna Industrial region, to mention only a few. As a result of wider distribution of many small nuclear power plants, even those regions of Europe deficient in raw energy (southern Italy, central Spain, etc.) would be able to develop some industry.

(2) Most water surplus regions have low population density, distances to the centers of consumption in some countries (for example, Sweden) have increased year after year since the war, and prices of electric power have increased accordingly. As mentioned earlier, economically advantageous hydro sites are becoming more and more scarce and the time is not too far distant when in certain countries the building of new hydro plants and the costly transmission network will equal or surpass that of building large or medium-sized nuclear power plants.

(3) The expansion of the European power network will be influenced greatly in the years to come by the close coordination between hydro, thermal, and nuclear power stations. At the present time the hydro power hinterland of the main Alpine producers (Switzerland, Bavaria, and Austria) is being expanded by costly transmission lines carrying surplus power to the consuming centers. Irregularities in the water regime, with resulting temporary power shortages, are assisted by thermal power plants. Obviously the ideal is obtained by interconnecting run-of-river stations with nuclear and modern thermal power stations. While these would be most economic for base loads, hydro storage plants, together with older thermal power stations and gas turbines, could be used at peak load demand.[68] Kaussmann and others draw the conclusion that regions of hydro power concentrations must either be supplemented (*durchsetzt*) by nuclear power plants or be surrounded by a belt of nuclear power plants, cooperating on a regional basis. The size of these nuclear power plants will depend on the size of the consuming area to be served.

(4) In those areas of Europe which at the present time are dependent upon expensive and often highly undependable coal imports (northern Italian industrial concentrations and Polish coal for the industries of the Vienna Basin) the need for an early realization of nuclear power becomes most urgent.

(5) Obviously the time will come when nuclear power will compete costwise with power produced in certain coal regions, for example, Belgium, France, Lower Rhineland, Midlands, etc. Power reactors, in such cases, will be located close to the coal fields, utilizing the present generating and transmission facilities supplying the same regions. In such a case larger reactors will be needed, reactors which can be used under high temperature and pressure.

(6) From information at hand, the conclusion can be drawn that nuclear power will reinforce rather than change present industrial patterns. Large industrial concentrations will favor either several medium-sized or large plants with a small transmission network, depending upon the costs. Because of the high cost of building nuclear reactors, the

[67] Several sources discuss locational factors for nuclear power plants. Of special interest to geographers are Sam H. Schurr and Jacob Marschak, eds., *Economic Aspects of Atomic Power* (Princeton: Princeton University Press, 1950), especially those pages dealing with selected industries, pp. 79–181; Walter Isard and Vincent Whitney, "Atomic Power and the Location of Industry," *Harvard Business Review*, Vol. XXVIII (March 1950), pp. 45–54 (even though this study was published six years ago it is still applicable to our present comprehensive knowledge of the problems of nuclear power). A most valuable short study is Kaussmann, *op. cit.*, from which a number of thoughts have been taken. Mention also should be made of a brief penetrating review by Stephen B. Jones, "The Economic Geography of Atomic Energy," *Economic Geography*, Vol. XXVII (July 1951), pp. 268–274.

[68] *Europe's Growing Needs of Energy*, *op. cit.*, p. 35. Thermal efficiency of generation, which is, on an average 23 percent, has been brought to 38 percent in the latest thermal plants. While costs for operating conventional power plants run approximately two-thirds for fuel and one-third for operating costs, including charges on capital, the ratio is reversed for operating nuclear power plants. It is thought that these costs can be reduced ultimately.

risk of locating reactors in underdeveloped areas is at present too great to materially affect the location distribution of manufacturing plants. Isard and Whitney, for example, argue that "cheap atomic energy might favor the concentration rather than the dispersal of industry."[69]

(7) The effect of new energy producing stations on locational changes of specific industries is most uncertain. There are no specific studies available which cite examples of prospective changes or effects in different European countries. On the other hand, Schurr and Marschak,[70] Isard and Whitney,[71] and Isard[72] discuss the over-all picture and cite specific industries with emphasis on the United States. Cockcroft, too, analyzes the over-all picture.[73] All of these studies agree that even the cost of greatly reduced energy will vary and its impact upon industrial locations would be far from uniform. The *Census of Manufacturing*,[74] for example, points out that in the United States the cost of fuel and purchased energy accounted for 5.9 percent of the value of products in 1939 for iron and steel products (except machines); 8.09 percent for clay and glass products, 2.5 percent for the textile mill products, but certain manufacturing processes, such as the production of aluminum, phosphate fertilizers, metallurgy, etc., spent as much as one-third of their cost for fuel and purchased energy.

Schurr and Marschak suggest that new industrial processes may bring locational changes,[75] but this, too, is still highly speculative. Obviously the cost of nuclear power will greatly influence locational changes in regard to industrial locations, but no revolutionary developments are at present in sight. With the great need for capital investment and a certain reluctance in experimental investments in Europe, any locational change due to changes in industrial processes is a long time off. The only change foreseeable in the near future may be the location of larger nuclear power stations near those processing industries using a large amount of electric energy, for example, cement, brick, pulp or paper, often some distance from fuel sources, or some of the industries listed earlier.

(8) Political developments can also be expected to affect the location of reactors producing nuclear power. Jones has observed that "political considerations may play an important and perhaps determining role in deciding if, how, when and where atomic energy is used for industrial purposes."[76] Various international organizations now are planning joint undertakings to ease the large capital outlay necessary to build nuclear establishments, and this may give greater emphasis to economic than political factors.[77]

THE EUROPEAN NUCLEAR ENERGY SITUATION

Present Nuclear Efforts

European scientists contributed much to the American atomic energy progress during the last 17 years,[78] but since the effects and after-effects of World War II directed all available energy of their own countries to rehabilitation, it is not surprising that the engineering development of atomic energy progressed much slower in Europe than in the United States. The difficulty of large-scale capital investments confined progress and actual experimentation to a few countries rich in available capital. Still countries such as The United Kingdom, France, Sweden, and Norway have achieved much progress in mastering the secrets of the atom and advancing from the drafting board stage to

[69] Isard and Whitney, *op. cit.*, p. 53.

[70] Schurr and Marschak, *op. cit.*, pp. 79–181.

[71] Isard and Whitney, *op. cit.*, pp. 45–54.

[72] Walter Isard, "Some Economic Implications of Atomic Energy," *The Quarterly Journal of Economics*, Vol. LXII (February 1948), pp. 216–229.

[73] Cockcroft, *The Future of Atomic Energy*, *op. cit.*, pp. 121–125.

[74] Vol. I, 1947, pp. 202–219, and Vol. II, 1947, Ch. VIII (Washington, D.C.: U.S. Government Printing Office, 1950).

[75] Schurr and Marschak, *op. cit.*, pp. 156–181, cite as one of their examples the iron and steel industry which, at the present time, in the United States at least, is favorably located with respect to coal. With the exception of the new and modern plants of the United Iron works in Linz, Austria, built during World War II, this also holds true for most of Europe.

[76] Jones, *op. cit.*, p. 273.

[77] Daniel Wit, "Some International Aspects of Atomic Power Development," *Law and Contemporary Problems*, Vol. XXI (Winter 1956), pp. 148–181.

[78] Among the many European scientists who have worked on atomic energy projects in the United States the following should be mentioned: Enrico Fermi (Italy), Niels Bohr (Denmark), Lise Meitner (Austria–Sweden).

important nuclear-research centers. Scientists who directed their energies toward the joint war effort have returned to their homelands —many of them were occupied during the war—and have become the nucleus of their countries' atomic energy efforts. Today knowledge of the peaceful use of atomic energy is available to all countries in the world. Available capital for investments for different types of experimental reactors, and a shortage of trained personnel are the greatest handicaps retarding progress in the field of nuclear power.

On the other hand, as preceding discussions have pointed out, the early use of nuclear power has become a matter of great urgency for most European countries. Therefore, in spite of higher costs[79] even in high cost energy countries—nuclear power stations are being built now to meet the increasing demands for electric power.

Europe as a whole is under-equipped in regard to nuclear energy,[80] in the number of trained scientists, technicians, and students, and in the expenditures budgeted for nuclear research.[81] While European research efforts have increased considerably during the last few years, larger nuclear installations have been confined, on the whole, to the United Kingdom, France, and perhaps four or five other countries. Latest available details are summarized in Table 7.

As can be seen from the above table, the British nuclear program is 'way out in front,[82] followed by the efforts of the French.[83] Belgium[84] is in a position to bargain for both American and British technical assistance because of her important uranium deposits. The Netherlands and Norway have developed a joint program of nuclear research, and Norway, the only European country with production of heavy water, occupies an especially strategic position. Even though her own interests lie largely in atomic energy for ship propulsion—to power the third largest merchant fleet in the world—her research reactor permits the export of isotopes.

On the other hand, there are a number of serious deficiencies. The only isotope separation plant is located in the United Kingdom and it is insufficient to provide for the needs of the continent. With the exception of the Uranium mines of the Erz Gebirge and the Massif Central, sufficient workable uranium ore deposits have not been found, even though considerable progress in prospecting was reported earlier in this study.

On the whole, the European nuclear effort has suffered from insufficiently integrated efforts, as well as insufficient investments by some countries.[85] This statement should not detract from the remarkable progress of individual countries, such as the United Kingdom and France, which, in spite of insufficient investments[86] have remained abreast in the tremendously costly nuclear developments. All this has pointed the way toward intra-European cooperation and several international organizations have proposed joint

[79]Nuclear installations in the United Kingdom at the present time are still expected to produce power roughly ten to twenty percent higher than in conventional thermal installations. A rapid reduction in cost is expected by British scientists according to reports presented at the 5th World Power Conference in Vienna, 1956.

[80]Not more than half a dozen prototype reactors and 12 research reactors are in operation or under construction.

[81]Important sources for general as well as specific European information have been found in the following publications: *Possibilities of Action . . ., op. cit., Nuclear Energy and the Production of Electric Power in Europe, op. cit.*; A. Winiger, "Atomkernspaltung und Energieversorgung der Zukunft," *Der schweizerische Energie Konsumer*, 1954; "Recent Atomic Energy Developments," Atomic Industrial Forum, Inc., September 1955, country reports; and the numerous country progress reports presented at the International Conference on the Peaceful Uses of Atomic Energy. Additional information has been obtained from various European journals, publications of the United Nations, O.E.E.C., and other international organizations.

[82]Cockcroft, *The Nuclear Power Program in the United Kingdom, op. cit.*, and *A Programme of Nuclear Power*, Cmd. 9389 (London: HMSO, February 1955).

[83]Andre Finkelstein, "The French Atomic Program," paper presented at Atomic Industrial Forum, Inc., September, 1955, pp. 494–498, and "Summary of French Nuclear Science," *France Actuelle*, Vol V (May 15, 1956), pp. 1–3.

[84]Louis De Heem, "Position of Belgium in the Atomic Field," paper presented at Atomic Industrial Forum, Inc., September 1955, pp. 482–486.

[85]*Possibilities of Action . . ., op. cit.*, p. 20.

[86]The United States invested approximately 15 billion dollars, the United Kingdom a little over 1.5 billion dollars, and France invested close to 250 million dollars. See also W. Kenneth Davis, "Capital Investment Required for Nuclear Energy," *International Conference*, Vol. I, pp. 290–302.

action to facilitate and hasten nuclear developments on an international instead of a national basis.

Joint Undertakings

There are many reasons why Europe must act quickly and effectively in coordinating to some degree the efforts of various countries in their research for production of nuclear power, and training of personnel. The capital outlay necessary to build nuclear power plants is not available in individual countries—the United Kingdom, France, and perhaps Western Germany are possible exceptions—but time is short for many countries if they wish to keep abreast of industrial and technological developments. The division of Europe between East and West has partly been overcome by cooperation sponsored through the United Nations International Atomic Energy Agency.[87] In addition, the United States, the United Kingdom, and more recently the U.S.S.R. have offered assistance to the European countries in the form of supplying experimental reactors, nuclear fuels, and technical aid. Besides joint research facilities at Meyrin, Geneva, under the sponsorship of the European Organization for Nuclear Research and the European Atomic Energy Society, two programs recommending several joint undertakings have recently moved toward closer realization. These two programs are (1) cooperation among the members of O.E.E.C.,[88] a "steering committee" for nuclear energy under the council of O.E.E.C., and (2) "Euratom" an organization sponsored by the Foreign Ministers of the Coal and Steel Community.[89] While each of the two programs now under discussion will include only certain European countries, each will greatly contribute toward pooling the resources of important industrial countries of Europe (see Table 7, A, B).

Both proposals recommend joint undertakings, but while "Euratom" proposes a supranational authority, including a monopoly for buying and selling, O.E.E.C. proposals remain more flexible, give more initiative to individual countries and private enterprise.

Earlier the importance of joint undertakings was stressed. All plans of cooperation now under discussion in Europe agree that such joint undertakings are essential if Europe wishes to compete successfully with the great powers, such as the United States and the U.S.S.R. Possible joint undertakings are:[90] (1) isotope separation plant, (2) one or more chemical separation plants for irradiated fuels, (3) plants to produce heavy water, (4) plants to produce "fuel elements from metal or oxide," (5) plants for conversion of ore into metal, (6) semi-industrial laboratories, such as material-testing reactors, centers for testing and basic metallurgical research, etc., (7) joint centers for the training of scientists and technicians (scholarships, perhaps a European Center for the teaching of nuclear science—an advanced scientific training center), and (8) a joint board of trade.

The construction of these proposed joint undertakings would be beyond the financial means of individual countries or companies. Not every country is in need of these costly installations. While O.E.E.C. proposes to form a number of companies to "finance and administer these undertakings," Euratom pro-

[87]A draft resolution is being prepared also at the United Nations, following President Eisenhower's proposal before the General Assembly in December 1953 "for international cooperation and international pooling of resources in the development of atomic power." "United Nations Draft Disclosed," The New York *Times*, April 26, 1956; also Wit, *op. cit.*, pp. 148–181.

[88]The following fields of cooperation have been suggested for the members of O.E.E.C.: (1) coordination of programs and projects, (2) promotion of joint undertakings, (3) harmonization of national legislation, (4) promotion of training, (5) promotion of standardization, and (6) system of international trade. For full details on each one of these points see *Possibilities of Action . . .*, *op. cit.*, pp. 21–40.

[89]"Euratom for First Political Test," *Bulletin, European Community for Coal and Steel*, No. 15 (May 1956), and "Euratom Takes First Step Toward a European Deal," The New York *Times*, June 3, 1956.

[90]For various detailed discussions see *Possibilities of Action . . .*, *op. cit.*, pp. 33–35, Appendices VII–X; Salomon Wolff, "Towards the Economic Integration of Europe," *Swiss Review of World Affairs*, Vol. V (January 1956), pp. 17–24, and, same author, "The O.E.E.C. Project for the Peaceful Development of Atomic Energy," *Swiss Review of World Affairs*, Vol. V (February 1956), pp. 17–19; also the monthly "Bulletins of the Coal and Steel Community."

poses to control those special undertakings fully or partially.

As to location of these joint undertakings, no detailed studies have been prepared, but obviously the choice will depend upon a number of economic, political and strategic considerations. The geographical distribution will be important—some may not wish to see all joint undertakings located within the same area; others may wish to create an extra-territorial region, locating a number of joint undertakings close together. Both proposals have merit, but the questions of accessibility, legal rights, and, more than anything else, willingness on the part of the country to give up some of its territory to an international organization, will play a decisive role, and at the same time will test the cooperation among some European countries.[91]

Probably the building and operation of an isotope separation plant will raise special problems, because of its high electric power consumption. Cost factors will be decisive here and it may very well be wise to locate this first joint undertaking near abundant cheap hydropower, instead of in conjunction with a nuclear power station. Norway, western Austria,[92] or Yugoslavia may offer ideal locations. Such a plant is urgently needed and hydropower at the moment is certainly competitive with power produced from atomic energy.

One other point of interest in connection with joint undertakings concerns the rapid changes in the technical methods of producing nuclear power which make it important to avoid too large or too many costly installations. Under these circumstances, it may be in the joint interest of the European countries to buy certain specialized materials from the United States, the United Kingdom, or the U.S.S.R. This would limit huge capital outlays, the money of which easily could be invested in furthering basic research and training. Also, certain important installations, such as metallurgical research in Plansee, Tirol, Austria, are already in operation in various European countries and might well be induced to cooperate with international organizations.

THE FUTURE OF NUCLEAR POWER IN EUROPE

Many reasons for the future importance of nuclear power to supplement Europe's increased energy demands have been given in the preceding pages. But perhaps the most important reason why atomic energy is attractive to so many countries is the fact that it can provide an additional energy source in the face of rapidly increasing population and an ever-increasing demand for electric energy. Unfortunately, dwindling reserves of hydro and lignite resources in many countries and high and rising costs of coal, which still provides more than 75 percent of the energy consumed in Europe, have brought to the forefront the consideration of an additional source of energy.

The future relationship between energy produced from conventional fuels and energy produced from nuclear fuels will be influenced by a number of factors. They are briefly summarized below:

(1) The future need of energy requirements in relation to the growth of the population and the general economic growth.

(2) The importance of guaranteed raw materials for the production of nuclear power.

(3) The availability of capital and technical know-how—this is of special importance to less developed countries. As Walker Cisler recently stated, "atomic energy will be more the stimulator of economic improvements than just solving economic problems."[93]

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[91] *Possibilities of Action . . ., op. cit.*, Annex IX, presents examples of extra-territorial agreements: the United Nations buildings and areas in Geneva, Switzerland, between the United Nations and the Swiss Federation of 1946; the United Nations property in New York, between the United Nations and the United States of 1947; the Basle–Mulhouse airport jointly constructed and operated between France and Switzerland since 1949; hydroelectric developments of contiguous rivers and lakes, etc.

[92] An excellent and detailed presentation of Austria's possible contributions has been written by Oskar Vas, "Zwischenstaatliche Wasserkraft- und Elektrizitaets-Wirtschaft und die Rolle Oesterreichs," *Svenska Vattenkraft-foreningens Publikationer*, 455 (1955: 14), pp. 253–292.

[93] Walker L. Cisler and Arthur S. Griswold, "Atomic Energy and the Electric Power Industry," paper presented for 27th International Congress of Industrial Chemists, privately distributed, September 15, 1954.

(4) The importance of solving a number of technical problems, such as the development of reactors to create heat at a temperature high enough to produce high thermodynamic efficiencies; extending the life of the reactor to keep interest and depreciation charges at a low enough level, for example, by the use of better structural materials, and better methods for the disposal of radioactive waste; the principle of breeding which should result in greater nuclear fuel efficiency; also the problem of recycling the "spent fuel."

(5) The small geographical variations of power costs, due to low cost transportation of atomic fuel, will influence the locational pattern of those industries where "low cost of fuel and/or power, or the availability of an unusually suitable fuel has been highly important in the selection of factory sites."[94]

(6) The extent of possible savings in costs over conventional fuels. Cost trends of past inventions indicate a rather substantial falling of capital costs once experimental work has been successfully concluded.[95]

In the discussion it has become clear that nuclear energy has certain very important advantages over conventional energy. Its greater mobility, efficiency, abundance, and hope for lower costs are the most promising factors in the competitive position between conventional and nuclear resources. What does this advantage hold for the future? Here we must base our conclusions on actual experiences of operating reactors, possible technological advances, and the result of experiments and careful evaluation.

The United Kingdom is the only country with a carefully prepared long-term plan which now is in actual operation.[96] Based on their urgent need for an additional energy resource and years of experiments in the peaceful use of atomic power, it is well to use this plan as a base for possible European development. At the same time, it must be understood that developments are different in different European countries, and reserves of conventional resources are not evenly distributed.

The United Kingdom is hopeful that by 1965 one quarter of all the new requirements in electric power can be covered by nuclear power stations, which should bring an annual saving of 5–6 million tons of coal. By 1970–75 all increased demands should be met by nuclear power. It is estimated by British authorities that this will bring an annual coal saving of 40 million tons. It is hoped that a similar amount could be saved from nuclear power stations in other O.E.E.C. member countries. But all together nuclear energy's contribution for Western Europe is not likely to provide more than 8 percent of the total energy demand.[97] It is estimated that after 1975 nuclear power will begin to influence more rapidly the energy balance and will be able to cover greater and greater electric power demands with emphasis on reduction of costs. More and more investments are expected to go into the new technological facilities. Planning for the future use of nuclear power can be accelerated by international cooperation as outlined earlier in this study. This cooperation should be made easier, according to a recent study by O.E.E.C., because the world is "at the outset of the atomic era, and it is always easier to cooperate on the new rather than the old."

The use of nuclear power in the years to come will vary from country to country, depending upon the cost of conventional versus nuclear fuels, the availability of conventional resources, and also upon the general political conditions. The United Kingdom, Belgium, Western Germany, France, The Netherlands, Denmark, Italy, and certain regions in nearly every country could make good use of an

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[94] Schurr and Marschak, *op. cit.*, p. 83. The analysis is based on the fact that all important costs with the exception of power remain the same and that new production processes based on atomic energy will be used only on newly built facilities to serve increased demands or to replace old existing facilities.

[95] Jules Wayne, "Post Geneva Economic Aspects of Nuclear Power," paper presented at Atomic Industrial Forum, Inc., September 1955, pp. 539–544.

[96] *A Programme of Nuclear Power*, *op. cit.*, and "Atomic Energy," *The Financial Times* (London), A Survey, April 9, 1956.

[97] *Europe's Growing Needs of Energy*, *op. cit.*, pp. 26–27.

additional source of energy at any time.[98] As time goes on, the use of coal will be pushed back to the mining centers where it can more successfully compete with nuclear power. Scientists also believe that chemistry will have important new uses for coal, while hydro power and nuclear power of the fast breeder type will ultimately be able to supply most of the necessary energy.[99]

The picture of the future use of nuclear power will then presumably look as follows: the next 8 to 10 years would be devoted largely to experimental nuclear power stations, even in countries that have urgent need for supplementary power, such as the United Kingdom. This stage would greatly benefit by closer international cooperation. One of the questions, for example, still wide open is which type of reactor is most promising, economically and from the standpoint of reliability and safety. The more numerous experiments in the United States could materially contribute to a solution of these problems in Europe.

[98]Western Europe's dependence on its oil supplies from the politically unstable Middle East is best illustrated by the examples cited below:

ANNUAL RATE IN MILLION METRIC TONS, BASED ON JANUARY–JUNE, 1956[1]

Country	Gross imports of crude and products	Exports (mainly to other European countries)	Net imports	Near East via Suez Canal	Supplies via pipeline (based on destination)
Belgium–Luxembourg	8.0	2.2	5.8	3.3	2.0[2]
Denmark	3.6		3.6	3.0	0.6
Norway	3.2		3.2	2.5	0.7
Switzerland	2.4		2.4	1.5	0.9
United Kingdom	39.8	7.2	32.6	23.3	3.5
France	26.0	4.8	21.2	13.8	10.0
Italy	18.2	5.8	12.4	8.6	7.0
Netherlands	15.2	8.3	6.9	9.0	[2]
Western Germany	10.4	1.0	9.4	1.5	2.0
Sweden	9.6		9.6	2.2	
Others	2.8	0.6	2.2	0.4	1.0
	139.3	30.0	109.3	69.1	27.8

[1]*Source:* Compiled from O.E.E.C. statistics.
[2]Including The Netherlands.

[99]Walker L. Cisler, "The Role which Nuclear Energy Can Play as an Energy Source in the Next 25–50 Years," *International Conference*, Vol. I (New York: United Nations, 1956), pp. 436, 441.

Once experiments have been successful, more electricity will be available from nuclear power and countries can gain experience in the operation and economics of nuclear reactors. This period is estimated to last until about 1975, at least. At the same time the need for power from conventional energy will by no means decrease. With coal production remaining stable and costs perhaps increasing, oil will assume a more and more dominant role in Europe's energy supply. For the most part, the more economical hydro power sites will have been used, but it is hoped that international cooperation in terms of interconnections, joint operations, and financing of plants will become an essential part of the European energy production. However, the total percentage, considering increased energy consumption, will not materially change.

Only after 1975 will the energy balance materially change. It is expected that the engineering problems of constructing large-scale nuclear power stations will have found their solution, and additional heat equivalent will be extracted per each ton of uranium or thorium. Slowly Europe's reliance on nuclear power as its primary energy source will increase. Many scientists feel that hydro and nuclear power will become ultimately the two main energy resources. Coal will either be confined to use close to the mines or "turned into coke for smelting and into coal tar, from which we shall need to extract countless plastics and chemicals, as well as the liquid fuels to replace oil products."[100]

Stephen Jones once raised the question if one ever would see a geography of atomic energy that is truly an economic geography, a geography uninfluenced by political developments and based purely on the economic needs of the people. In Western Europe, at least, there is a better than even chance of accomplishing this, and there is much hope for the world as a whole. International cooperation, as expressed by numerous international organizations, is seriously working on various projects and the International Conference on the Peaceful Uses of Atomic

[100]John Gray, "Power and Water," Part 1 of "A Survey of World Resources," *Progress*, Vol. XLIV (Summer 1955), pp. 228–236.

Energy in Geneva during 1955 and the World Power Conference in 1956 are examples of scientific and political cooperation in the interest of world peace. There is no subject more worthy of cooperative thought than the future of atomic energy.

NEW POPULATION MAPS OF UGANDA, KENYA, NYASALAND, AND GOLD COAST

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IN 1954 I collaborated in the publication of a study on the population geography of humid tropical Africa[1] in which distribution of native people was represented on a small-scale dot map and a choropleth map. The data used in the construction of these maps were the latest available in early 1953. Because of the very small scale at which the two population maps of tropical Africa were reproduced, they were capable of exhibiting only the broader outlines of distribution, so that the text accompanying the maps focused upon only the larger elements of population arrangement.

Most conspicuous on the small-scale population maps of tropical Africa referred to above is the fact that the African natives are concentrated in two widely separated general regions, one in western and the other in eastern tropical Africa, where the overall density is 10 to 100 persons per km^2. These two regions of concentration are separated by a central African area where the average density is only 3.4 persons per km^2. In the West Africa-Sudan region the bulk of the inhabitants live within three large, discontinuous subregions, two of them coastal belts and the third an irregular and discontinuous one roughly paralleling the coast at a distance of 400-500 miles inland. The East African concentration, chiefly in the plateau area, is characterized by a highly complex alternation of spots of high and low density.[2]

With the assistance of graduate students an attempt has been made to analyze in greater detail the distributional elements of population in four of the political subdivisions of tropical Africa.[3] One of these, the Gold Coast, lies within the West Africa-Sudan region of population concentration and the other three, Uganda, Kenya, and Nyasaland, belong to the East African region of higher-than-average general density and of complex distribution.[4]

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[1] Glenn T. Trewartha and Wilbur Zelinsky, "Population Patterns in Tropical Africa," *Annals*, Association of American Geographers, Vol. XLIV (1954), pp. 135–162.

[2] *Ibid.*, see Figs. 1a, p. 140, and 1b, p. 141.

[3] The graduate students assisting in the study and responsible for the original maps and reports of individual areas are as follows: Uganda, Robert B. Reece; Kenya, Roy Chung; Nyasaland, Gene E. Musolf; Gold Coast, Glenn V. Fuguitt. The original map of the Gold Coast prepared by Mr. Fuguitt was of the choropleth type and he was responsible for the accompanying report. Using the same data an isoline map for the Gold Coast was prepared by Albert Farley and Reginald Marshall and it is this map which is here reproduced.

[4] A list of the more recent and detailed published items containing population maps of the four political units included in this study are as follows:

East Africa:

S. J. K. Baker, "The Distribution of Native Population over East Africa," *Africa*, Vol. X (1937), p. 43. Small-scale dot map covering Uganda, Kenya, Tanganyika, and Ruanda-Urundi.

S. J. K. Baker and R. T. White, "The Distribution of Native Population over South-east Central Africa," *Geographical Journal*, Vol. CVIII (1946), p. 201. Small-scale dot map covering Katanga, Nyasaland, Rhodesias, southern Tanganyika, and northern Mozambique.

Carl Troll, "Weisser Siedlungsraum in Afrika," *Koloniale Rundschau*, Vol. XXVII (1936), pp. 437–44. Covers Uganda, Kenya, Tanganyika, Ruanda-Urundi, and Zanzibar; scale approx. 1:7,000,000; one dot equals 1,000 persons and in congested areas 5,000.

Kenya:

Elspeth Huxley and Margery Perham, "Kenya—Native Population," in *Race and Politics in Kenya; a correspondence between Elspeth Huxley and Margery Perham* (London: Faber and Faber, 1944). Scale approx. 1:10,000,000; one dot equals 5,000 persons; 1940 data.

Nyasaland:

F. Dixey, "The Distribution of Population in Nyasaland," *Geographical Review*, Vol. XVIII (1928), p. 276. Scale 1:4,625,000; six density patterns.

Uganda:

H. G. Thomas and Robert Scott, *Uganda* (London: Oxford University Press, 1935), p. 272, "Uganda Protectorate; Distribution of Native Population." Scale approx. 1:3,500,000; one dot equals 1,000 persons.

Gold Coast:

Gold Coast Survey Department, *Atlas of the Gold Coast* (Accra, 1949), pp. 4–5. Scale 1:1,500,000; six density patterns.

R. W. Steel, "The Population of Ashanti: A Geographical Analysis," *Geographical Journal*, Vol.

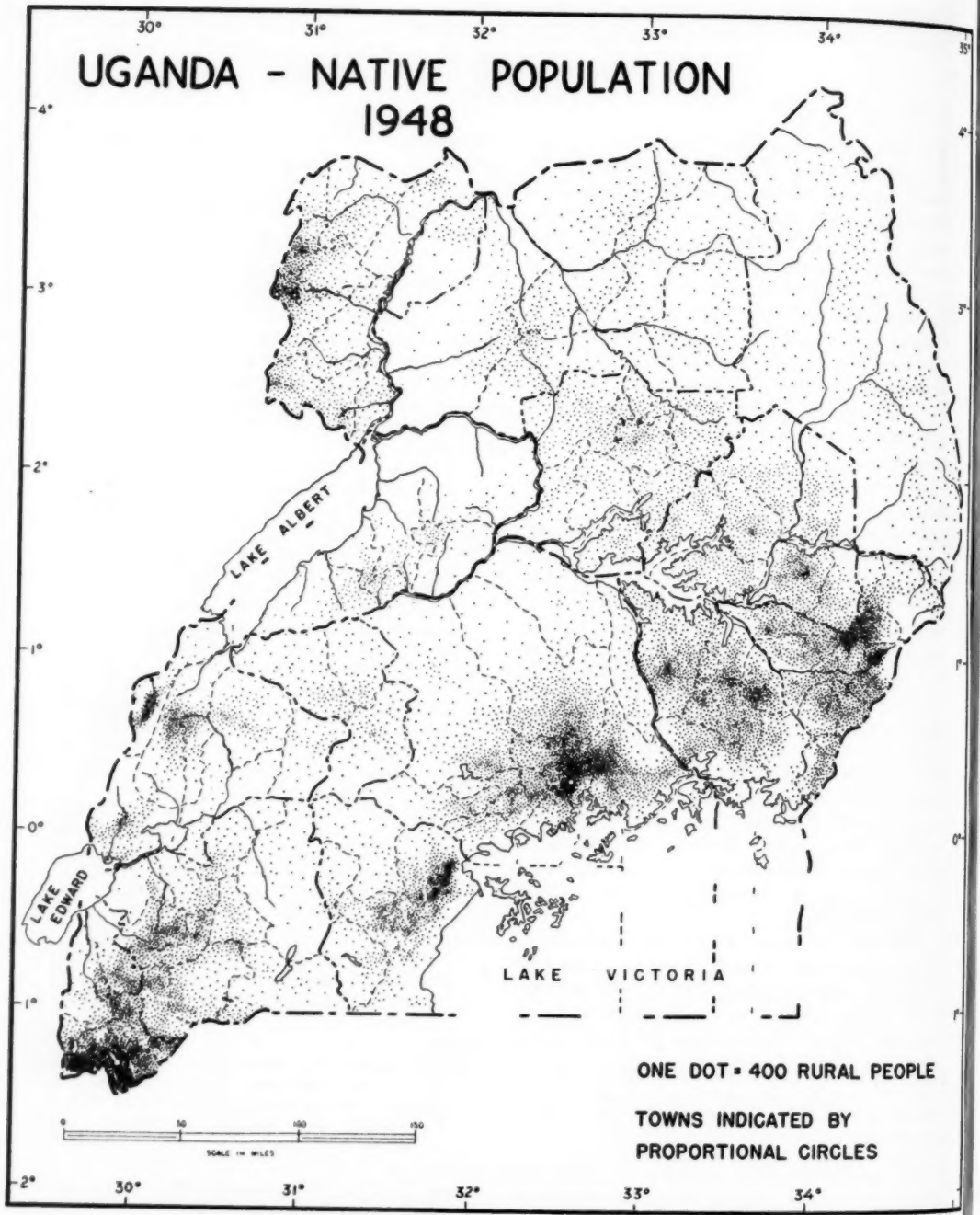
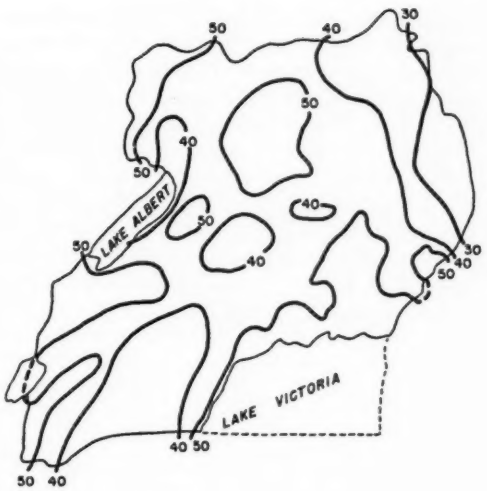


FIG. 1. Native population is relatively widespread in Uganda for rainfall is more abundant and reliable here than in most of East Africa. Map by Robert B. Reece.

UGANDA

In the construction of the population map of Uganda (Fig. 1) the data source employed was the East African Population Census of 1948.[5] The long and detailed planning which preceded this census suggests that it represents a relatively accurate count of the population.[6] With an area of about 80,000 square miles of land surface, the Protectorate is divided into a hierarchy of political subdivisions consisting of four provinces, 15 districts, over 90 counties, and about 550 subcounties. Population data are tabulated by each of these classes of political subdivisions. In addition data are given for the main native tribes of the districts and subcounties. A map, scale 1:1,000,000, published in 1950 by the Survey, Land and Mines Department of the Uganda Government provided the boundaries and the names for most of the counties. Sources identifying the precise locations of the subcounties and the tribes were not available, so that their population data could be located only approximately and by indirect methods. However, the 1:500,000 sheets of East Africa, No. 4355, British War Office, while they do not show county and subcounty boundaries, do have on them a goodly number of subcounty names in the form of names of tribes, villages, trading centers, or triangulation stations. These names, in conjunction with other evidences of settlement, were used in locating the dots representing subcounty populations. Unfortunately, the subcounties of Masaka, Mubende, Mengo, and Busoga districts are given only as titles of native chiefs for which there are no names on the map sheets.

Other aids in revealing the distribution of native population were also provided by the East Africa maps. Descriptive legends, such as "dense cultivation," were particularly useful. So also were such cultural features as stores, missions, dispensaries, cotton markets, cotton granaries, and roads. Certain kinds of physical areas designated as swamp, rugged



ANNUAL RAINFALL
(INCHES)

FIG. 1a. Uganda rainfall distribution.

POPULATION REGIONS

NUMERALS • AREAS OF POPULATION CONCENTRATION
LETTERS • AREAS OF SPARSE POPULATION

FIG. 1b. Uganda population subdivision.

CXII (1948), pp. 64–77. P. 68, "Ashanti, Density of Population, 1921"; scale approx. 1:4,000,000; four density patterns. P. 71, "Ashanti, Distribution of Towns, 1931"; scale approx. 1:4,000,000; all towns over 1,000 represented. Facing p. 76, "Ashanti Distribution of Population"; scale 1:1,000,000; dot symbols representing buildings and villages shown on 1:250,000 maps of Gold Coast Survey.

[5] *African Population of Uganda Protectorate*, East African Population Census, 1948, Geographical and Tribal Studies, Nairobi, 1950.

[6] C. J. Martin, "The East African Population Census, 1948; Planning and Enumeration," *Population Studies*, Vol. III (1949–1950), pp. 303–320.

terrain with steep slopes, thick thorn bush, and those infested with the tsetse fly affecting humans, were assumed to be sparsely populated unless there were positive cultural indicators of close settlement. Such descriptive titles as "thorn and scrub," "uninhabited," "dense forest," and "dense bamboo" were heeded, as were "game preserves" and "forest reserves." In areas of predominantly pastoral economy, watering points, such as springs, waterholes, and wells, were judged significant as indicators of population. The above remarks are included because they point to important indirect ways and means for determining population distribution which can supplement those provided by census data for minor civil divisions.

The population of Uganda in 1948 consisted of 4,918,000 natives and 41,000 nonnative peoples. The latter, chiefly from tropical southern Asia and Europe, are highly concentrated in the towns and trading centers. Thirty seven percent are in the three main towns of Kampala, Jinja, and Entebbe. It is obvious from Figure 1 that the 4.9 million native peoples are distributed very unequally throughout the 80,000 square miles of land surface. The arrangement is a difficult one to describe for it has no easily discernible pattern which is related to any known arrangement of other geographical features. In the description to follow six centers of relatively high density and two of low density are singled out for brief comment. Urban population is neglected since the total number in the seven places with over 2,000 inhabitants is only 40 to 45 thousand. Bantu Negro peoples comprise about 63 percent of the native population; the Nilotes, who are Hamiticized Negroes speaking a Sudan tongue, about 20 percent; and the Nilo-Hamites, a mixed group, about 14 percent. The Bantu are Negro cultivators with whom cattle raising usually is of secondary importance. The Nilotes are both cultivators and keepers of cattle, while the Nilo-Hamites are chiefly pastoralists. A reasonably accurate generalization may be made to the effect that Bantu peoples occupy chiefly the southern half of Uganda, the Nilotes the west and northwest, and the Nilo-Hamites the east and northeast.[7]

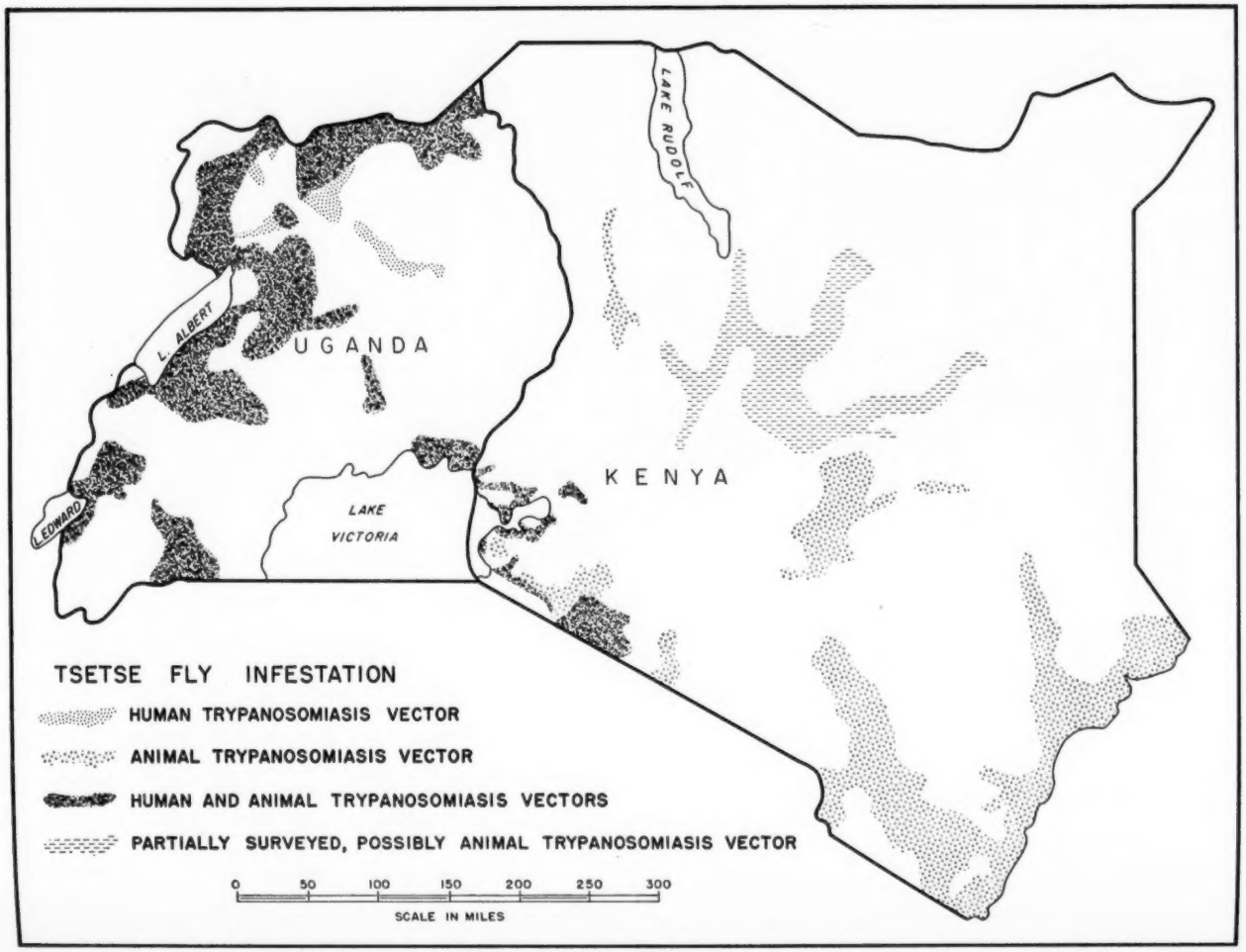
[7] *The East African Royal Commission 1953–1955 Report* (Cmd. 9475; London, 1955), pp. 11–12.

The Mt. Elgon-Lake Victoria region (1 on Fig. 1b) in eastern and southeastern Uganda is the largest and, on the whole, most densely settled part of Uganda, containing roughly 45 percent of the native people. This is one of the two population regions possessing rail service. Most of this extensive area appears to have been characterized by political stability, settled agriculture, and a relatively dense population for a period reaching well back into the past. Its inhabitants are predominantly the Basoga, Baganda, and other Bantu tribes who are traditionally agriculturists, although not without some livestock. It needs to be emphasized that population differentials in East Africa are quite as frequently related to tribal cultures as they are to physical attributes of the land. In general the physical equipment provides a relatively favorable environment for native agriculture. The 45 to 55 inches of rainfall are moderately dependable and well distributed seasonally. An elevation of approximately 4,000 feet ameliorates the equatorial heat. A vegetation cover of tall grass and scattered trees is an indicator of soils superior to those developing under a short grass cover which prevails over much of the Protectorate. The water supply is adequate throughout most of the region and the human and animal tsetse are absent except along some of the coastal margins of Lake Victoria and the islands adjacent (Figs. 1a, 2, 3).

The Bantu peoples of this region practice a semisedentary agriculture, the basic population unit being a single isolated farm family operating a holding of 5-10 acres on which food crops, as well as commercial crops of cotton, coffee, or tobacco, are produced.

Within the Mt. Elgon-Lake Victoria population region there are significant variations in population density. One rather striking concentration is coincident with the western and southwestern slopes of volcanic Mt. Elgon in Mbale district of easternmost Uganda. Here the soils developed from basic lavas are unusually fertile. This local area of high density continues across the political boundary into Kenya. Rather distinct clusterings of population are likewise to be observed farther to the southwest in the Mengo and Masaka districts fronting on Lake Victoria. The metropolis of Kampala serves as the center of the Mengo

FIG. 2. Infestation by human or animal tsetse, or by both, greatly handicaps extensive areas of Uganda and Kenya for native settlement. From folded map No. 3 contained in *The East Africa Royal Commission 1953–1955 Report.*



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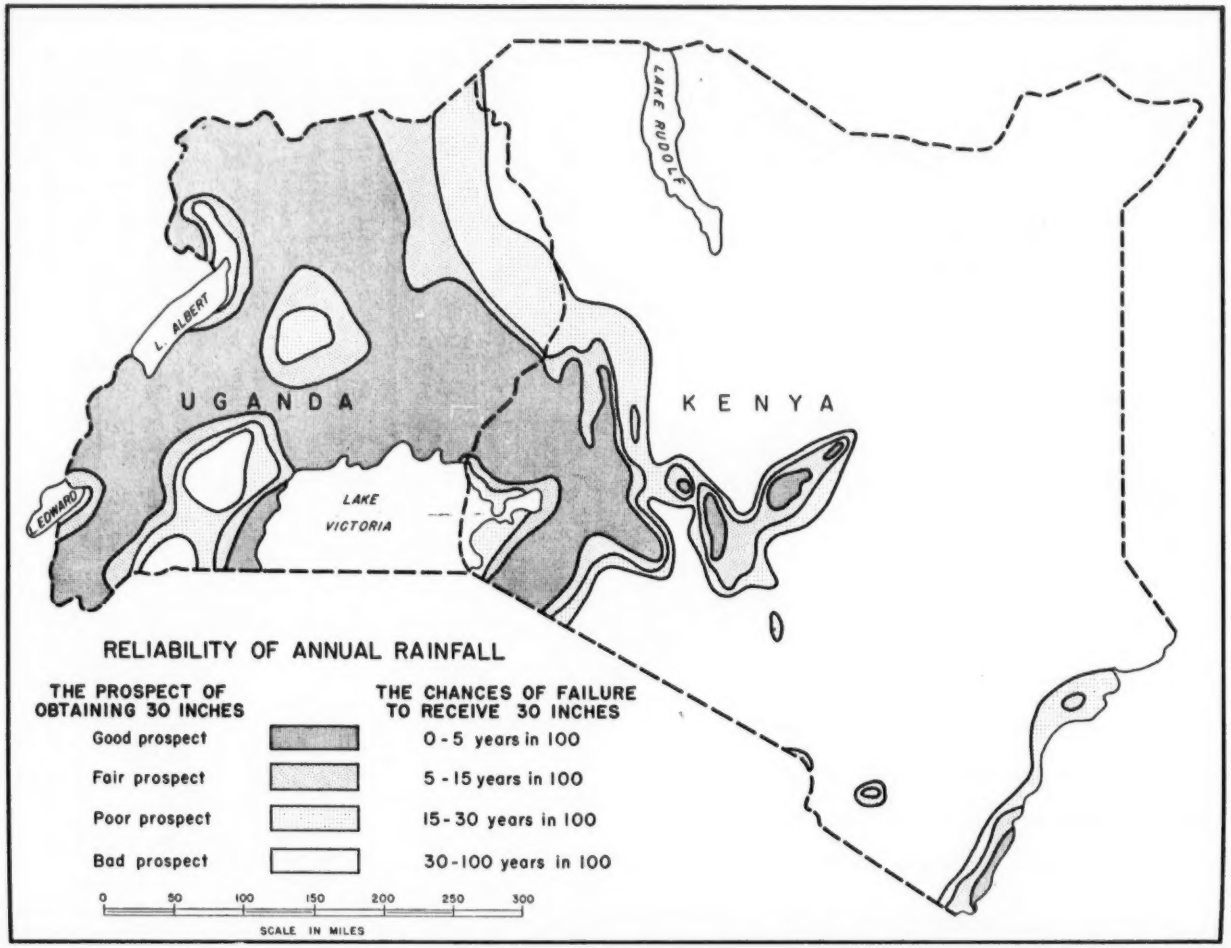

FIG. 3. Rainfall unreliability in Uganda and Kenya is an important factor affecting the distribution of native population. Important cultivation is excluded from those areas where, on the average, one in three years receives less than 30 inches of rainfall. Most of Kenya is so afflicted. Over most of Uganda there is a good prospect of receiving at least 30 inches of rainfall in more than 85 percent of the years. After Map 3 in *The East Africa Royal Commission 1953–1955 Report*.

cluster. It appears as though the individual clusters of population within the Mt. Elgon-Victoria region are largely a consequence of isolation produced by low, poorly drained riverine lands, which in some sections are actual lakes.

The Lango region (2 on Fig. 1b) lying to the north of riverine Lake Kyogo, which separates it from the Mt. Elgon-Lake Victoria region, has a total population of 743,000 inhabitants, so that its over-all density is less than that of the former region. Here rainfall is less bountiful, short grass takes the place of tall elephant grass so that the soils are less well nourished, and cattle raising is a more important part of the native economy. In fact, this is the most important cattle region in Uganda. Much swamp land is present, some of this wet land drying up sufficiently in the dry season so that it can be grazed. This emphasis on pastoralism which is reflected in a population density that is only one-third to one-half that of the Mt. Elgon areas just to the east, may in part reflect a somewhat inferior agricultural resource base, but it likewise is a consequence of the Nilote and Nilo-Hamite peoples who predominate in this locality of Uganda. Most of the inhabitants belong to the Lango and Iteso tribes whose cultures combine pastoral activities and rudimentary cultivation in various forms and intensities. Much of the population appears to live in small agricultural villages.

The Southwestern Upland region (3 on Fig. 1b), lying east and south of Lake Edward and occupying the southern part of Kigezi, and the southwestern part of Ankole provinces, contains about 725,000 native inhabitants. In general density, therefore, it rivals the Mt. Elgon-Lake Victoria region, although its total area is much less. The most closely settled part is in the extreme southwest in Kigezi district, which, demographically speaking, is an extension into Uganda of a larger populous region which includes much of Ruanda-Urandi. One needs to be cautious about seeming causally to relate the spots of denser population in Africa to superior physical environments for agriculture, and such is the case in this instance. For although the general altitude of over 5,000 feet, the absence of animal tsetse, localized areas of superior soils, and the fairly plentiful water supply are assets of some consequence, there are offsetting factors in the form of swamps, steep slopes, and thin stony soils, so that in its entirety the region does not appear to possess an unusually choice environment for native agriculture. Without much doubt an important contributing factor in explaining this local population concentration is the fact that the occupants are almost exclusively Bantu tribes (Banyankole, Bakiga, Banyaruanda) most of whom are traditionally agriculturists. Toward the east, as rainfall reliability becomes less, tsetse common, and cattle raising an important element in the native economy, population declines rapidly (Fig. 3).

The West Nile region (4) in the extreme northwestern part of Uganda includes a native population of about 329,000. Along the western boundary where it joins the Belgian Congo the land reaches elevations of 4,000 to 6,000 feet, while the valley of the Nile along the eastern border is only 2,000 feet above sea level. Population is concentrated on the higher western lands where rainfall is relatively abundant (Fig. 1a) and tsetse absent. The lower eastern country, toward the river, is handicapped by smaller annual rainfall and is infested by tsetse (Fig. 2). In this general region the natives are Nilotes who are mainly cultivators although cattle raising is combined with different forms of shifting cultivation. Since 1915 the Administration has set and enforced fixed boundaries between tribes, clans, and villages so that the earlier fluidity of population, which made for density homogeneity, is now absent. As a result the highly differential local rates of population increase can no longer be equalized by migration so that there has come to be a serious maldistribution of people with respect to the capacity of the land. Consequently the people of one village may be living at a far higher nutritional density than those of a neighboring village, with the understandable friction that such disparities generate. Out-migration has been one solution for local overpopulation, and from some overcrowded districts in the western parts one-fourth of the adult men may be absent at one time.[8]

The Ruwenzori (5) and Bunyoro (6) re-

[8] J. F. M. Middleton and D. J. Greenland, "Land and Population in West Nile District, Uganda," *Geographical Journal*, Vol. CXX (1954), pp. 446-455.

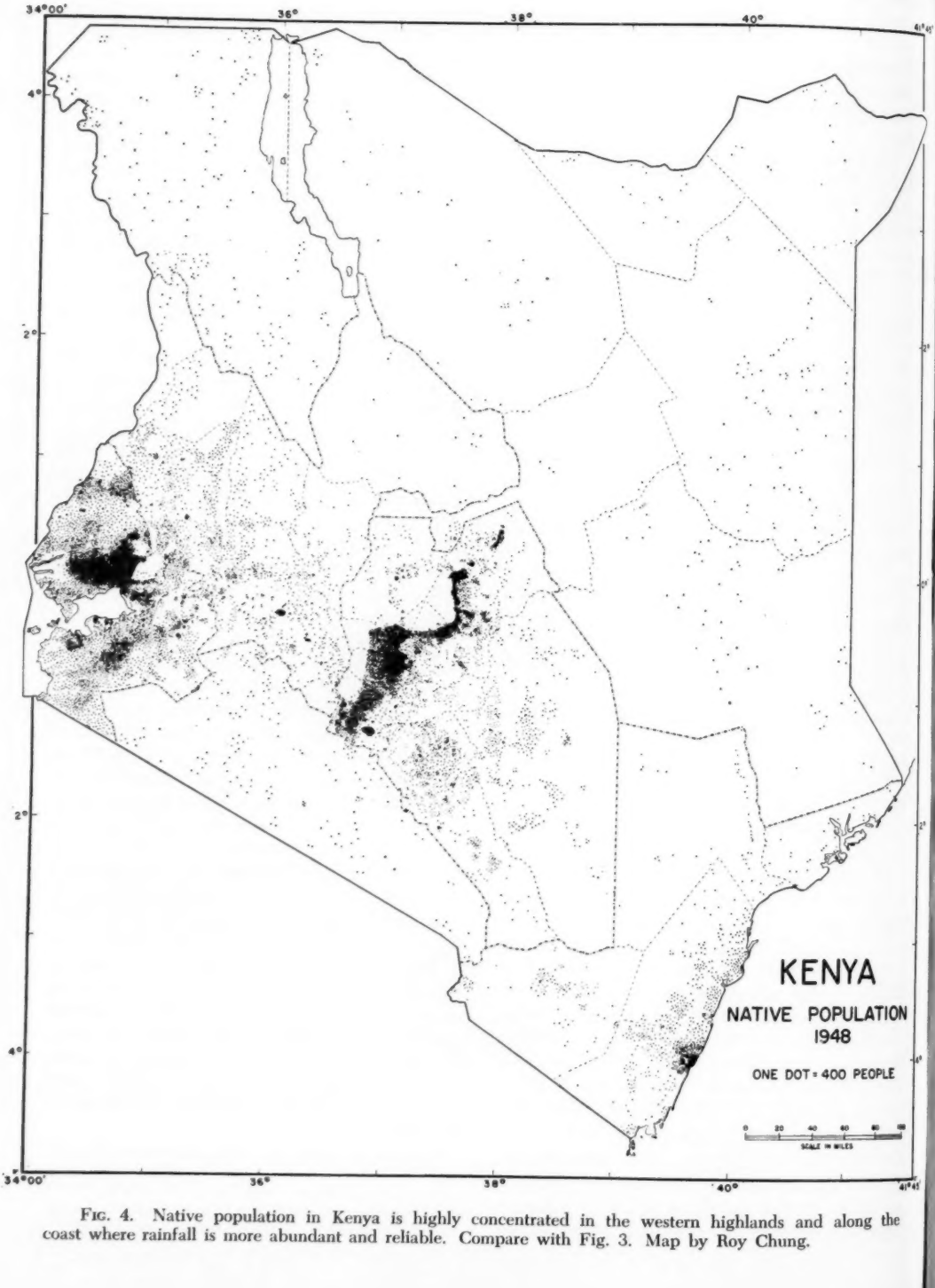

FIG. 4. Native population in Kenya is highly concentrated in the western highlands and along the coast where rainfall is more abundant and reliable. Compare with Fig. 3. Map by Roy Chung.

gions in western Uganda represent smaller and less compact clusters of native population.

Two general areas of sparse settlement can be recognized in Fig. 1, a relatively compact one in the north and northeastern part of Uganda (A, on Fig. 1b) and another much less compact one in the south and west which represents the general space outside the isolated areas of higher density (B, on Fig. 1b). There is no strong coincidence of these more empty areas with any single element, or simple combination of elements, which might offer an easy explanation for the less complete settlement. The reasons are complex and in many instances even unknown. Inadequate and variable rainfall, and deficient water supplies of all kinds are handicaps that plague extensive sections of the empty areas (Fig. 3). This, no doubt, is the most widespread handicap. Game preserves coincide with some of the smaller voids on the population map. Livestock and human tsetse are a discouraging factor over extensive areas with sparse population (compare Figs. 1 and 2). Added to these natural handicaps is the factor of native culture, for most of the occupying tribes belong to the Nilote and Nilo-Hamite groups among whom the tradition of sedentary agriculture is less strong than it is with most Bantu tribes, and pastoral use of the land more common. It is not unlikely that some of the meagerly settled country if it were in the hands of Bantu tribes with an agricultural tradition would show a greatly increased population.

KENYA

According to the 1948 census, Kenya with an area of 224,000 square miles supported 5,406,000 people, over 97 percent of whom were native Africans. With a total population only slightly larger than that of Uganda and a land area that is 2.8 times as large, Kenya's overall population density is less than two-fifths that of Uganda. The 154,000 nonnatives, chiefly Arabians and Indians, are not considered in this report.

The data source for the detailed statistics used in constructing the population map of Kenya is the East African Population Census of 1948.[9] Like Uganda, Kenya is divided into

[9] *African Population of Kenya Colony and Protectorate*, East African Population Census, 1948, Geographical and Tribal Studies, Nairobi, 1950.

KENYA
AVERAGE ANNUAL RAINFALL

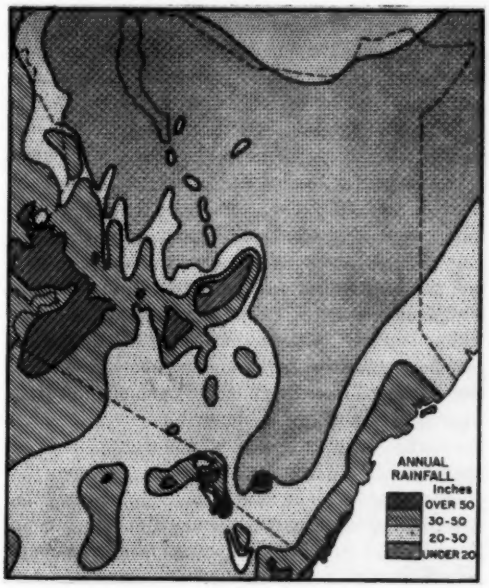

FIGURE 4a.

KENYA
POPULATION REGIONS

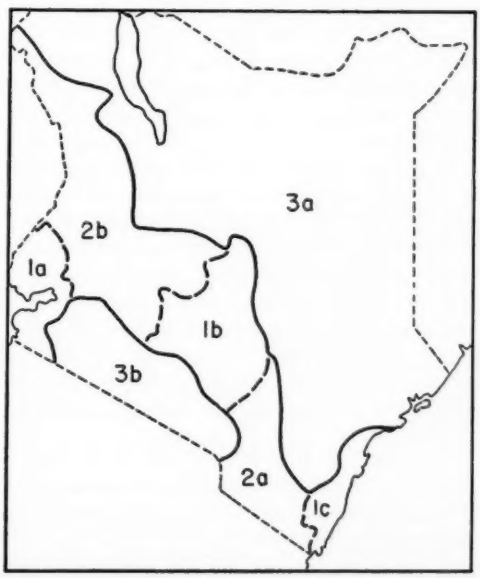

FIGURE 4b.

a hierarchy of political units consisting of provinces, districts, and locations. Within the locations the data are further broken down into tribes. The enumerated native population amounted to 5,030,000; the population of the Northern Frontier Province, not enumerated, is estimated at 219,000.

Provincial and district boundaries were obtained from a map, scale 1:1,000,000, entitled "Kenya, Political and General," published in Nairobi in 1951. It was a simple matter, therefore, accurately to apportion the correct number of dots by provinces and districts. The genuinely difficult problem was that of fixing the positions of the very numerous tribal locations, population data for which are provided by the census report. A personal letter from the Acting Director of the East African Statistical Department in Nairobi stated: "There are certainly no maps on which these locations are marked. They are demarcated on the ground by local knowledge." This being the case, the actual areal extent of the tribal locations could not be delineated and only approximate positions could be determined using four different series of large-scale maps (1:50,000; 1:500,000, 1:1,000,000 and 1:2,000,000). Of additional aid in this respect was *Gazetteer No. 1, British East Africa* (United States Board on Geographic Names, 1955), which gave locations of many of the tribal areas in degrees and minutes of latitude and longitude. A native schoolmaster from North Nyanza was able to demarcate the approximate boundaries of the tribal locations within that district.

Using the census data, the precise patterns of the dots for the tribal locations were determined from information regarding villages, huts, and kraals as contained on the large-scale maps. The 1:50,000 maps were made from air-photo mosaics and therefore were considered to be of the highest accuracy. These maps cover only a small portion of Kenya, but fortunately the areas so covered are some of the most densely populated in the colony.

Like most of East Africa, Kenya is characterized by striking inequalities in the spread of population. The most noteworthy feature as shown on Fig. 4 is the band of relatively high densities, composed of clusters of high density separated by areas of more moderate occupance, which extends from the northeastern shores of Lake Victoria in the extreme west, to the coastal plains around Mombasa in the east. This irregular belt of above-average density contrasts strikingly with the relative emptiness of the northern and northeastern parts of the colony and the sparseness of the extreme southern districts. As a general rule the regions with fewest people, both to the north and the south, are handicapped by unreliable and meager precipitation (Fig. 3 and Fig. 4a). This is especially true of the very extensive northern and northeastern parts of the colony. On the other hand, an environment-oriented explanation is inadequate to account for some features of the general pattern just described, and certainly for many of the density variations within the population belt.

Within the population belt three nodes of relatively dense settlement are conspicuous: (1) the Nyanza node, (2) the Central Highland node around Nairobi, and (3) the Mombasa or Coastal node (see on Fig. 4b areas designated 1a, 1b, 1c).

The Nyanza node (1a). The Nyanza node population cluster is roughly coincident with Nyanza Province, omitting Kericho District. It is one part of a more extensive belt of population partly surrounding Lake Victoria. The high degree of population concentration here is suggested by the fact that although this province represents only 5 percent of Kenya's land area, it does, on the other hand, support nearly 35 percent of the colony's population. Nyanza's overall density of 168 per square mile is high by African standards for rural people. The reasons for this concentration of people are complex. In general the physical attributes are considerably above average for the colony. Rainfall averages 40 to 60 inches and is moderately reliable (Fig. 3 and Fig. 4a); the 3,000 feet of elevation ameliorates somewhat the tropical heat, and the volcanic and red-earth soils, especially in North Nyanza, are well above average for the colony.[10] But these elements are permissive only and they scarcely account for the considerable density variations within the general node.

[10] G. Milne, *The Soils of Kenya Colony and Protectorate*, explanatory memoir accompanying, "A Provisional Soils Map of East Africa" (East African Agricultural Research Station, Amani, 1936), p. 22.

Of great consequence in explaining density differentials in tropical Africa are the social and economic quantities of the different native tribes. Thus the populous region around Lake Victoria is peopled largely by Bantu tribes which are largely sedentary agriculturalists, in contrast to those tribes occupying the highlands east of Nyanza Province who are half-Hamites and predominantly pastoral in their economy. There population is much less dense. Thus the abrupt termination of the high densities of the Nyanza node on its eastern margins is partly of cultural origin. In part the break is coincident with the Nandi Escarpment and with forest reserves.

Within the general Nyanza node there are conspicuous differentials in population density. In the area of highest density just to the north of Navirondo Gulf there is one locality of about 40 square miles where the density exceeds 1100 per square mile. In these parts almost every bit of arable soil is exploited to the limit and pasture land is so scarce that cattle and sheep are tethered while grazing and the fertile soil is made to yield two crops a year.[11] Farther to the north is another local area of relatively high density coincident with the fertile soils along the foothills of volcanic Mt. Elgon. Here a more extensive type of native cash-crop farming has developed as a result of the impact of European culture in the adjoining Kitale–Eldoret region. In South Nyanza agricultural settlement is more restricted by reason of swamps, steep slopes, rocky soils, and tsetse fly infestation. Local relief is greater than to the north and lowland areas are more limited in extent.

The Central Highland node (1b). In the Central Highland node the elevation approximates 4500 feet and the annual rainfall averages 30 to 60 inches and over (see Fig. 3 and Fig. 4a). Within the general node of high density there are striking variations in closeness of settlement. Three subzones are recognized: "a," the very dense north-south zone which curves around the eastern and southern flanks of Mt. Kenya; "b," another area of moderately high densities farther to the east in Machakos–Kitui districts; and, between these, "c," a region of sparser settlement. The westernmost concentration coincides fairly well with that part of the Central Highlands which is not alienated to Europeans. On its western margins the belt of high density is abruptly terminated by the forest preserves which occupy areas on Mount Kenya, the Aberdare Mountains and the Kikuyu escarpment. To the east of the narrow belt of high density is broken hilly country, where rainfall drops off sharply and the vegetation cover is chiefly scrub vegetation. Within the belt of high density the rainfall averages 40 to 70 inches and the soils are represented as being the best within the colony.[12] But no combination of physical elements is able to explain absolute and relative densities of population. This populous highland belt with its adequate rainfall, modest relief, and fertile soils was formerly sparsely occupied by a hunting tribe known as the Doroba, and it was only with the coming of the agricultural Kikuyus in modern times that the resource base has been more fully exploited and population has greatly multiplied.[13]

In the eastern or Machakos–Kitui district, densities are only moderate; nevertheless there is a serious local overcrowding of these marginal lands.[14] Rainfall averages only 30 to 40 inches and is unreliable, and the upland surface is crossed by numerous barren ranges of hills. The primitive agricultural practices of the Bantu–Akamba tribes who inhabit the area have caused a serious deterioration of the scattered utilized spots while the number of cattle, sheep, and goats is greatly in excess of what the natural range can support.

The Mombasa Coastal node (1c). The Mombasa Coastal node is much the smallest of the three concentrations of Kenya's population and also is the only one situated at low elevations. It is roughly coincident with a narrow coastal belt of heavier precipitation to the west of which is dry country with less than 20 inches of rainfall (Fig. 4a). The core of this coastal node is the port and rail-head city of Mombasa with a population of about

[11] Günter Wagner. *The Bantu of North Kavirondo* (Oxford University Press, 1949), Vol. I, p. 15.

[12] G. Milne, *op. cit.*, p. 21.

[13] H. Martin Leake, "Studies in Tropical Land Tenure—East Africa," *Tropical Agriculture*, Vol. IX, No. 11 (1932), pp. 346-350.

[14] *Land and Population in East Africa* (Great Britain, Colonial Office, 1952), p. 2.

85,000. Within Coast Province there is a non-native population of about 50,000, chiefly Arabs and Indians, who are principally engaged in commercial activities in the port towns and cities. The Bantu natives are largely agriculturists, although a significant number of them find employment in the urban centers and on the sugar cane and sisal plantations of the British colonists.

Between the three nodes of highest population concentration previously described, and linking them into a somewhat amorphous east–west belt of settlement concentration, are transitional areas where native peoples are present in intermediate numbers (Fig. 4b). The easternmost of these (2a), separating the Highland and Coastal nodes, is debatably even transitional for, except for a few spots such as the Teita Hills and in the neighborhood of the Voi-Teita railway, "the country is uninhabited and all but waterless, a desolate expanse of thorns, scrub and flat-topped acacias."[15] It comes very close to qualifying for classification as an area of sparse settlement. Over large parts the annual rainfall averages less than 30 inches. Much of it is included within the Tsano National Park.

The second transitional area (2b) within the population belt separates the Nyanza and Central Highland nodes. Since much of it lies within the Rift Valley Province of Kenya, that title is reasonably satisfactory for the population subdivision as well. It includes extensive areas of the Kenya Highland that have been alienated to the Europeans, as well as others occupied by the half-Hamitic tribes whose economy is dominantly pastoral, some being primarily nomadic and others sedentary and engaging in considerable cultivation. Rainfall varies between 30 and 50 inches, but it is the occupying groups and their economies more than the rainfall that have resulted in the over-all moderate density as well as the local patterns of distribution. For the Rift Valley Province the average density is only 26 persons per square mile. Physical factors such as slope, local relief, soils, and water supply are important criteria underlying the evaluation of desirable sites for occupance. But the Europeans and the Africans evaluate these factors differently, resulting in significant differences in the distribution of their enterprises and multiplying the complexity of the intraregional population pattern. Forest reserves account for some of the larger areas which are relatively free of native people. Large European plantations devoted to coffee, sisal, and tea explain other similar but less extensive open areas. Most of the compact clusters of dots signify small trading centers of a few thousand inhabitants.

Kenya's extensive sparsely settled areas are two in number, a very large northern and eastern one (3a) and a smaller southern one (3b). Within the northern area rainfall is generally under 20 inches. This arid and semiarid climate imposes definite limitations upon the over-all character of land use. Population density averages about 2 persons per square mile.[1] Nomadic Hamitic and half-Hamitic tribes provide a large proportion of the total population but even these people tend to concentrate in the more favorable sites where water is available. Some of these sites are near water holes and wells, others are in stream valleys, while still others are higher elevations where rainfall is somewhat more abundant.

The southern Masai area (3b) has a population density of only 4 persons per square mile. Over the central and eastern part rainfall is between 20 and 30 inches although its western parts are distinctly more humid, and fitted for uses other than grazing (Fig. 4a). This is the realm of the Kenya Masai, a half-Hamite group which in its social and economic organization epitomizes the nomadic pastoral peoples of East Africa. Among them the warrior class is dominant. Their animals not only are an economic asset but represent "security in social relationships, legal affairs, and religious ritual."[16] Concerning these pastoralists one writer has noted, "their life shows in an unusually clear way how completely a cultural bias and traditional mode of life may determine and restrict the use of territory which offers other possibilities."[17] Thus the over-all low density of the Masai area involves primarily the factor of culture, supplemented

[15]John Parkinson, "A Note on the Taita Hills, Kenya Colony," *Geographical Journal*, Vol. CI (1943), p. 161.

[16]E. R. Ervine, "Health and Agriculture in Africa," *African Affairs*, Vol. LIII (1954), p. 136.

[17]D. Daryll Forde, *Habitat, Economy and Society* (London, 1952), p. 306.

by features associated with recent political history, incursions of epidemic diseases, rainfall deficiency, and tsetse-fly infestation. On the map some of the principal linear concentrations of dots lie in proximity to transportation lines which follow the main valleys.

NYASALAND

According to the 1945 census,[18] Nyasaland Protectorate with 37,000 square miles of territory has a de facto population of 2,050,000, 99.7 percent of which is native and Negro. The characteristic settlement unit of these agricultural peoples is the small hamlet averaging about 40 persons per cluster. Because of the large out-migration of adult males seeking employment in adjacent colonies, the sex ratio greatly favors females (115.8 to 100) while for the population over 18 years of age the ratio is 146 to 100.

As in most of East Africa, the spread of native settlement in Nyasaland is very uneven. Thus, while the average density for the whole colony is 55.7 persons per square mile, that for Southern Province is 83.2 and for Northern Province is only 27.3. Almost 50 percent of the total population is concentrated in Southern Province in about one-third of the area, while Northern Province with almost the same area has only 14 percent of the people. Among the smaller political subdivisions the density variations are still greater, from a low of 12.2 in Kasungu District in Central Province to a high of 310.2 in Chiradzulu in Southern Province.

On Fig. 5 two principal concentrations of populations are to be noted, one in the Shiré Highlands in Southern Province and the second on the Angoniland Plateau in Central Province.

All or parts of five districts comprise the Shiré Highlands and in each of these subdivisions density of native population exceeds 100 per square mile, while in one it is over 300. This concentration of native peoples appears to be of recent date for late in the last century the Shiré Highlands were a region of sparse settlement. It is chiefly the employment possibilities provided by the tobacco, tea, and tung estates of the European settlers which have attracted the natives to the region, a large number of the immigrants originating in adjacent Mozambique. In the 20-year period prior to 1945 native population in the Shiré Highland cluster increased by as much as 250,000.

Actually most of the Shiré Highlands have been alienated for European settlement so that the Negro agriculturists are technically squatters. Some 72 percent of the alienated lands are in the hands of eleven corporate estates. The landless natives pay their rent not in cash but in labor and are obliged to give one to six months of labor in lieu of cash rent. Following the example set by the Europeans, the natives not living on estate lands have likewise turned to commercial crops, so that there has come to be an increasing pressure of population upon the food supply. The three towns of any size, two with about 4,500 people and the other with 7,100, are concentrated in this southern cluster. Altitudes of 3,000–7,000 feet and moderate annual rainfalls of 45–55 inches provide a general environment in the Shiré Highlands which is relatively attractive for agriculture.

The Angoniland Plateau in the central part of the colony, which is the second large region of concentrated native settlement, roughly coincides with an elevated area where outcrops of crystalline limestone and graphitic gneiss, according to the former state geologist, Frank Dixey, foster the development of better-than-average soils. Most of the non-Africans of Nyasaland, outside of Southern Province, are concentrated in this region where tobacco is a specialty crop of both Europeans and natives. Some of the tribal groups specialize in cattle which they market in the Southern Province.

Other less conspicuous concentrations of population in Nyasaland are:

1. On the alluvial lands bordering Lake Nyasa and along the larger river valleys draining into this lake from the west. The fertile soil, and food in the form of fish from the lake, are special attractions.

2. Along the valley of the Shiré River which exits from the southern end of Lake Nyasa. On the fertile alluvial soils of this valley there has come to be a considerable specialization in cotton and tobacco culture.

Nyasaland is a region of large-scale emigration as well as immigration. In 1950 it

[18] *Nyasaland Protectorate, Report on the Census of 1945* (Government Printer, Zomba, 1946).

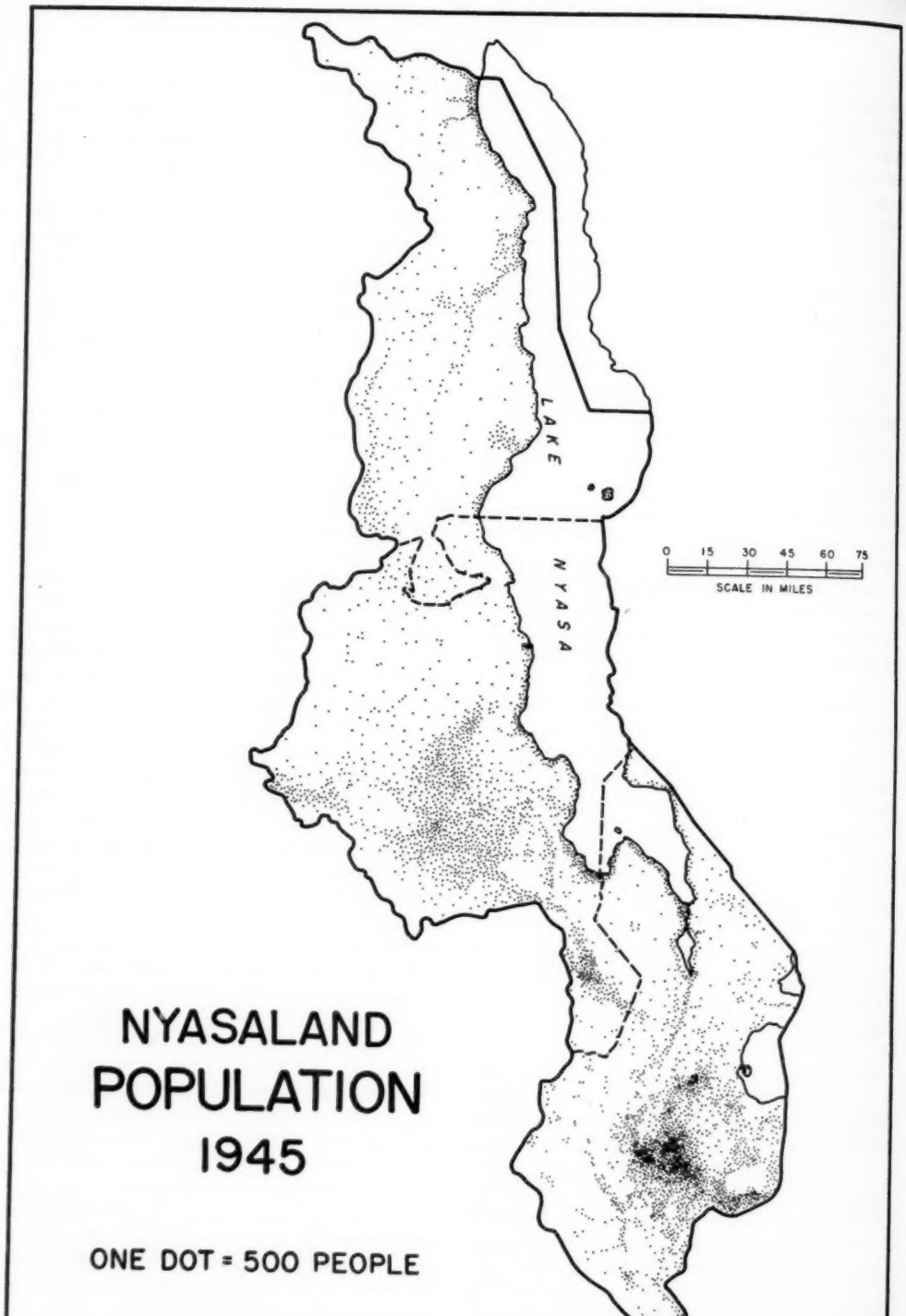

FIG. 5. Map by Gene E. Musolf.

was estimated that 143,000 Africans were absent from the Protectorate, of whom 87,000 were in Southern Rhodesia and 40,000 in the Union of South Africa. A large proportion of this out-migration (both temporary and permanent) has occurred since 1940. The "Dead North" country furnishes most of the emigrant laborers, chiefly because of the meagerness of economic opportunities in that section.

GOLD COAST

As Uganda, Kenya, and Nyasaland are all parts of the general East African population region characterized by a relatively high overall population density, but also by close juxtaposition of spots of high and low density, so the Gold Coast is one unit of the West African region of relatively high density. Moreover, it has sufficient latitudinal spread so that it includes portions not only of the coastal subregion of higher density but of the interior discontinuous belt of denser settlement as well. Within the 90,000 square miles comprising the Gold Coast there were, according to the 1948 census,[19] 4,118,000 inhabitants, representing an average density of about 45 per square mile. There are fewer than 7,000 non-Africans, so that this 0.16 percent of the population may be neglected in the present study.

In contrast to the three regions in East Africa previously analyzed, the Gold Coast has a much larger proportion of its population concentrated in urban settlements. Some 13 percent of the people reside in places with 5,000 or more inhabitants and the combined populations of the 37 urban places amount to 530,000. Although most of the 6,800 non-Africans live in the towns, the urban places are obviously almost as completely Negro in composition as is the countryside. A high degree of concentration of the cities and towns lies in the southern part of the dependency, particularly in The Colony Administrative Area, which contains 76 percent of the entire urban population. Twenty-five of the 37 urban places are located within an approximate triangle whose points are the three largest cities: Accra (135,000) and Takoradi-Sakondi (45,000) located on tidewater, and Kumasi (60,000) in the interior. A great majority of the urban places function as trading centers although a few may be overgrown farm villages. Commercial native agriculture, emphasizing chiefly cacao, and important mining operations have been largely responsible for the surprisingly large urban expansion in recent decades, although many of the cities had their beginnings at a much earlier date.

The 3,600,000 inhabitants, or 87 percent, who are classed as rural, are grouped in a very conspicuous gross pattern. Fifty-one percent is concentrated in the southern administrative area, known as The Colony, with the highest densities in a broad belt oriented east-west and relatively parallel with the coast (Fig. 6). A second area of moderately high density is located along the extreme northern, and especially the northeastern, margin of the Gold Coast in what is Northern Territories. Between these two regions of more concentrated settlement is a very extensive central area where settlement is sparse, large areas having average densities or less than 10 per square mile. There is a smaller area of low density in the extreme southwestern part of the Gold Coast, in the westernmost part of the Colony Administrative Area. These features of gross distribution of population are not so easily explained. In part, they no doubt have their roots in the tribal history of the past few centuries, a history for which there are few written records.

The Gold Coast central belt of sparse settlement appears to be part of a more extensive middle belt of generally low density which lies at the northern fringes of the forest at about 7½° to 10° N. throughout the Guinea Coast provinces (see Figs. 1a and 1b in Trewartha and Zelinsky, pp. 140–141, *op. cit.*). Within the Gold Coast central belt very infertile sandstone soils are widespread. In its broader eastern section, which is fairly coincident with the Volta River basin, the lowlands are subjected to widespread inundation in the wet season while the higher sites, which are the most desirable for village location, are lacking in water during the dry season.[20]

[19] *The Gold Coast Census of Population 1948, Report and Tables* (The Crown Agents for the Colonies, London, 1950).

[20] A. W. Cardinall, *The Gold Coast* (Accra, 1931), p. 70. See also, R. W. Steel, "Land and Population in British Tropical Africa," *Geography*, Vol. XL (Jan. 1955), p. 13.

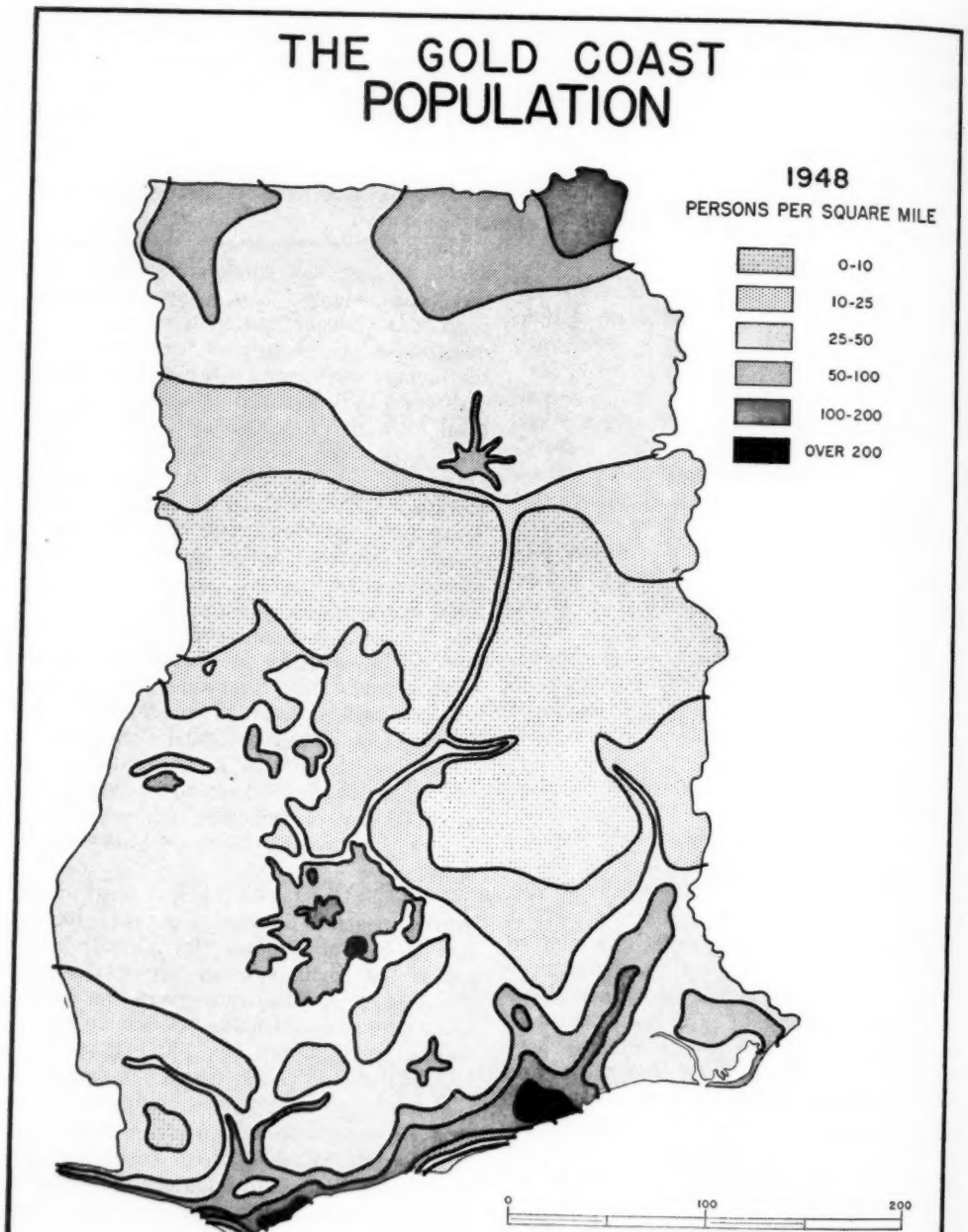

FIG. 6. Population in the Gold Coast is concentrated in the south and to a lesser degree in the north. The central part has few people. Map by Albert Farley and Reginald Marshall.

Additional discouraging features are the prevalence of the tsetse, the general lack of significant mineral resources, and the inability to grow cacao. The higher and better-drained western part of the central belt of sparse settlement may owe its low density in part to slave raiding. A. W. Cardinall, the chief census officer of the 1931 census, has suggested that the small, isolated, low-density area lying within the forested belt in the extreme southwestern part of the Gold Coast may owe its meager settlement to the fact that it had not developed in time to profit by the cacao boom.[21] Walter Fitzgerald has related the low density of this same area to its heavier rainfall and denser rainforest.[22]

The smaller and less important of the two regions of population concentration, that in the northern part of the Gold Coast, presents something of an unsolved problem. It appears to be a part of an interrupted east–west Sudanese belt of denser settlement which reaches from French Guinea in the west to Lake Chad in French Equatorial Africa. There seems to be no explanation which applies to the belt in general, its different parts having unique and distinctive interpretations. Certainly the northern part of the Gold Coast is far from being an attractive area for agricultural settlement. Still it is somewhat more elevated than the region to the south and consequently is not plagued by serious floods. In addition it lies in an area of crystalline rocks and north of the general region of infertile sandstone soils.[23] The densest settlement area in the extreme northeast is the southern part of a more extensive and very ancient area of population concentration in the upper Volta region, chiefly in the French Sudan. Slave raiding and tribal warfare may account for the declining population densities westward from this northeastern concentration.

The southern region of population concentration, containing two-thirds of the Gold Coast's inhabitants, in some degree reflects the attractiveness of proximity to the coast, for with the exception of the dry littoral around Accra, the density of settlement decreases from the coast inland. The restricted belt of highest densities widens somewhat from west to east following the isohyetal pattern. Since the general concentration of rural people in the humid, forested south antedates the modern exploitation of minerals and cacao in the region, this fact of distribution cannot, in the main, be attributed to the recent development of commercial towns and cities associated with mining and commercial agriculture. Comparing the census figures for 1921, 1931, and 1948, there appears to be no strong coincidence between the localisms of rural population change and those of urban change. Nevertheless, it can scarcely be otherwise than that the modern emphasis on commercial cacao growing and mining in the south has served to strengthen a southern and coastal concentration of rural population already present at an earlier period. The interior spot of above-average density lies in the vicinity of the inland metropolis of Kumasi.

Most of the rural native people of the Gold Coast live in agricultural villages, many of them of relatively large size so that the ultimate detail of population distribution shows strong nucleation. One-fourth of the rural people are in settlements having 1,000 to 5,000 inhabitants. An additional one-third live in settlements containing 500 to 1,000 persons. The remainder are in smaller settlements.

SUMMARY

If there is any generalization that can be drawn from the maps and discussion of population distribution within the four political units here represented, it is to the effect that the present pattern of population inequalities in East and West Africa do not consistently reflect the qualities of the resource base. It is even difficult to define the term "quality" as applied to resources, since that attribute is as much a function of the cultures of the numerous tribal groups as of the physical environment. To be sure, such physical features as a serious deficiency of rainfall, widespread poor drainage, and high and rugged terrain do impose definite settlement limitations upon all groups of natives. But within environments

[21]Cardinall, *op. cit.*, p. 157.

[22]Walter Fitzgerald, *Africa: A Social, Economic and Political Geography of Its Major Regions* (6th ed.; London, 1948), p. 352.

[23]R. J. Harrison Church, *West Africa* (London, 1957), Chap. 23.

which are permissive of agricultural settlement there are striking localisms of population concentration which quite as often are cultural or traditional rather than environmental in their origins. And since tribal culture traits are exceedingly slow in their transfer or diffusion from one group to another, it is common to find contrasting densities of native settlement even within what appear to be relatively similar environments. Thus, tribal tradition, expressed through attachment to a particular area, even when it is poor and unproductive, appears to explain some of the apparent inconsistencies of population concentration which reveal inferior lands to be crowded while adjacent higher-grade agricultural environments are only thinly occupied.

Unfortunately the literature dealing with specific regional and tribal cultures and economies in Africa is seriously deficient. Representing the two extremes are the nomadic pastoralists and the sedentary people supported by tillage. But even among the latter there are wide differences in intensity of land use which in turn are reflected in population density variations. Still another factor tending to complicate the population pattern in West Africa is the effect of slave raiding which tended to depopulate certain districts. In both East and West Africa the consequences of tsetse infestation cut across tribal as well as environmental patterns.

PRE-BUILDING GROWTH PATTERNS OF CHICAGO

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Subdivision and sale of lots are the first stages in the preparation of nonurban land for urban use. The developing pattern of prepared land is, therefore, the framework within which the expansion of the built-up area of a city occurs. Although physical (*i.e.*, "built-up") expansion has frequently been studied and regular development patterns have been described, no comparable investigation of basic pre-building growth patterns has been attempted. This paper traces the changing patterns of land subdivision and sale within corporate Chicago; it correlates them, by maps, with transportation lines, parks, and settlements and with historical conditions; and it examines the relationship between the city's actual pre-building growth patterns and existing theoretical descriptions of physical urban expansion.[1]

Land subdivision and sale do not proceed regularly in all directions from an urban nucleus. Within corporate Chicago, the patterns of subdivision and individual lot sale display most irregular outlines at all periods during the city's growth.[2] That irregularity, apparent in Figures 1 and 2, implies differences in the real or assumed suitability of peripheral districts for urban development. In general those differences reflect the presence or absence of transportation lines, existing settlements, or outlying parks. Frequently, however, only the fancied salability of some districts in preference to others underlies the differences. In contrast to the spatial variations, the times and rates of Chicago's growth are related to historical and economic conditions.[3] Both spatial and temporal elements will be discussed here.

The pattern of initial subdivision[4] growth, presented on Figure 1, shows no uniformly timed or spaced outward growth from a central core. Rather, during limited periods of time great bursts of subdivision activity occurred and wedges of prepared land were pushed outward into still rural territories. Outliers of subdivision, separated from the developing city by intervening unprepared land or representing spread from detached settlement nuclei, are important elements in the pattern. Periods of inactivity, when few new territories were subdivided or during which interstitial areas were prepared, were followed by renewed subdivision activity under pressure of other and later land booms.

Irregular as the subdivision growth pattern of Chicago is, it shows more uniformity in direction and time than does the pattern of individual lot sale.[5] Individual lot sale (Fig. 2) proceeded at a slower rate than did initial subdivision; the areas included in any one

[1]The research reported in this paper was partially supported by funds of the Research Board of the Graduate College of the University of Illinois; that assistance is gratefully acknowledged. The courteous cooperation of the officers and staff of the Chicago Title and Trust Company is particularly appreciated. Their generosity in permitting me access to their magnificent land records and assistance in the use of these records made this study possible. Herbert L. Slutsky and Joseph A. Fekete, Research Assistants in the Department of Geography, rendered valuable aid in the preparation of this study.

[2]"Growth" is used here to refer to all phases of subdivision and sale preceding building construction.

[3]For a classic account of this aspect of Chicago's physical expansion, see: Homer Hoyt, *One Hundred Years of Land Values in Chicago* (Chicago: University of Chicago Press, 1933).

[4]Basic data on initial subdivision, resubdivision, and individual lot sale in Chicago were secured from the records of the Chicago Title and Trust Company. Figures 1, 2, and 19 have been based upon land records for the northwest one-quarter of each quarter section of the city; the figures for each stage of land development calculated for each sample area were extended to include the quarter section in which the sample area lay. The data of this study, then, are calculated from a regularly distributed sample amounting to 25 percent of the total area of the legal city of Chicago.

[5]Individual lot sale is taken as an indication of acceptance of subdivided land by private purchasers who acquire property presumably with intent to utilize land for urban purposes. Chicago Title and Trust Company records do not note land uses or the nature or date of first structures on the land. Data for Figure 2 ignore transfers of blocks or clusters of lots and are based upon an average date for each northwest one-quarter of each quarter section when one-half or more of the lots had been purchased by individuals not parties to previous land sales in the same sample area.

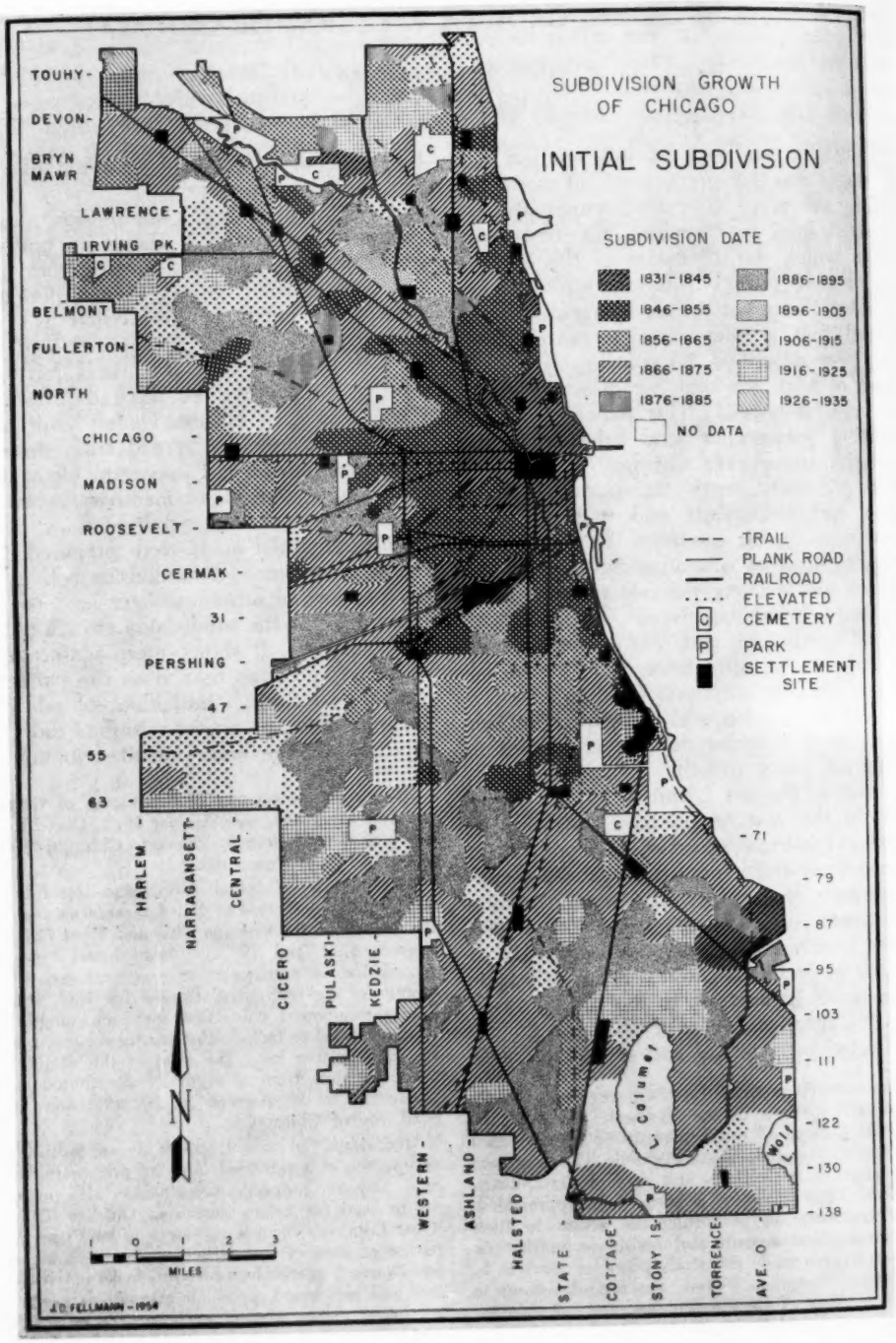

FIG. 1 The growth of Chicago through initial subdivision.

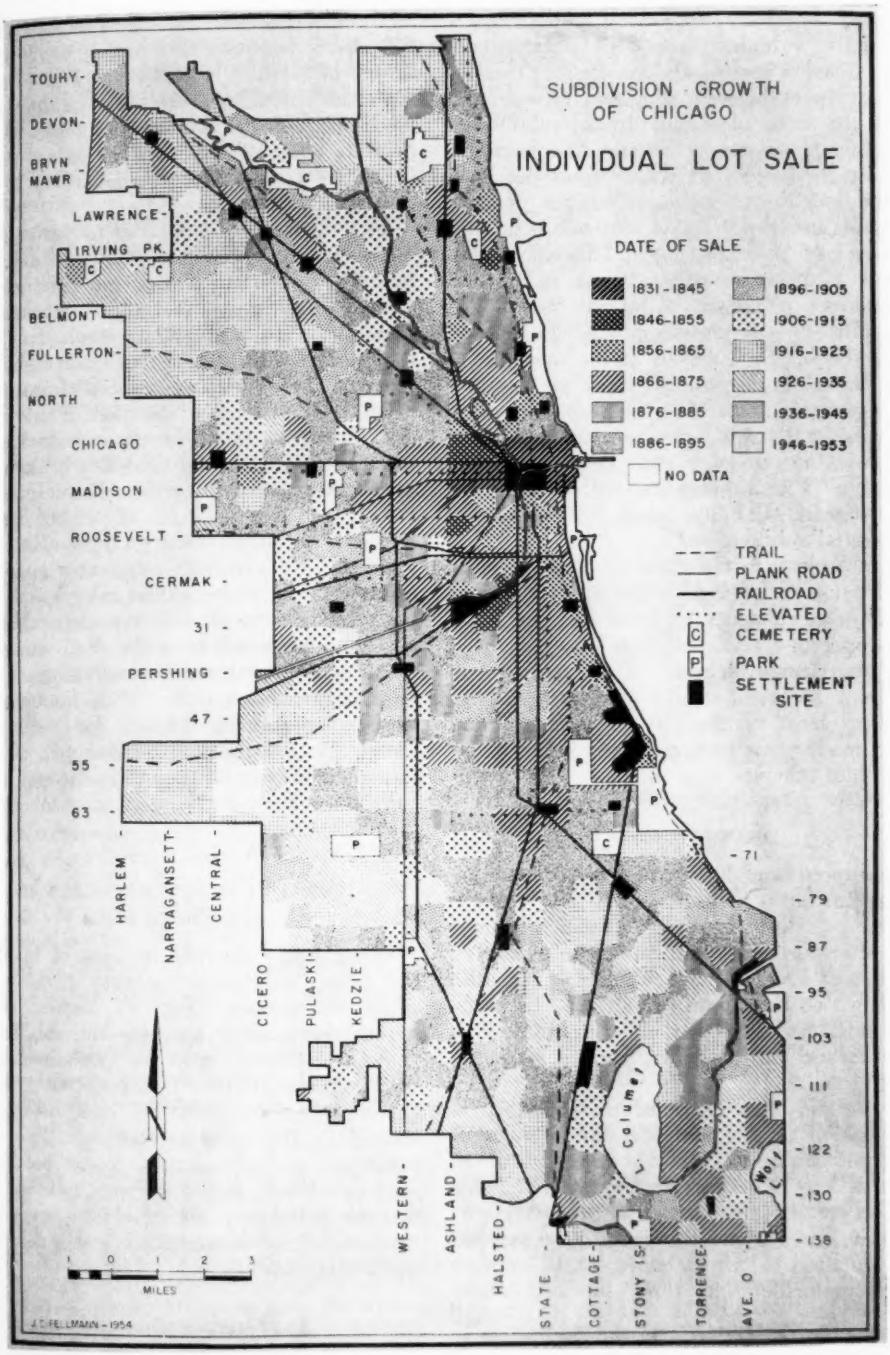

FIG. 2. The growth of Chicago through individual lot sales.

mapped period are smaller and more irregular and have a higher degree of discontinuity than areas of initial subdivision.

Differences between the two growth patterns are to be expected. Initial subdivision in Chicago was very largely a speculative activity, in large part based upon the legal rather than the physical preparation of land. It rarely involved erection of urban structures on the land prior to sale and therefore produced a growth pattern based upon land speculators' estimates of lot salability. The individual lot sale pattern in Chicago is based upon the buyers' analysis of the usability of land for urban purposes. It therefore involved the decisions of many individuals influenced by considerations of price, accessibility, physical condition, prestige, etc. These individual decisions (Fig. 2) were less uniform than the estimates of salability made by a relatively few initial subdividers.[6]

Nonetheless, in the patterns of both initial subdivision and individual lot sale the effects of definite elements of areal differentiation are apparent. Transportation lines imparted disproportionate degrees of accessibility to different sections on the periphery of the built-up areas of the city; settlements and parks made some sections more or less favorable than others.

TRANSPORTATION

Transportation lines have not invariably been stimulators of initial subdivision or individual lot sale in Chicago. In general, intercity transport lines appear to have had a significant effect on land subdivision but little influence on individual lot sales. Local transport lines had a greater effect on individual lot sales and only a slight attraction for initial subdivision.

These and other relationships between land preparation or sale and the development of different transport systems are shown on Figures 3 to 14 and are summarized in Table 1. The relationships are not, of course, simple. In those cases where there is a close association of areas to two or more transit systems nearly coincident in time, no satisfactory method of isolating the effect of one of the systems is possible. For example, the areas shown in relation to railroads (Fig. 4) overlap areas correlated with other transportation media or cultural features. Because of this overlap, some of the same areas are shown as in the same temporal relationship to two or more features.

Two devices are employed in this study to minimize such areal and temporal overlaps. First, the districts shown on the maps as related to an individual feature are generally limited to the area within one-half mile of the feature. This spatial restriction eliminates some of the overlap of associated areas that occurs when larger subdivision or sale areas are considered. It also limits consideration to those lands that would most clearly show any existent temporal correlation. Second, emphasis is given to a span of only eight years: a five-year period *after* the establishment of the cultural feature—within which any immediate effect on subdivision or lot sale should have been apparent; and a three-year period *prior* to the establishment of the feature—within which any anticipatory subdivision or sale might have taken place. This limitation of time span further reduces the degree of doubt about the effect, for example, of each transport line in areas where two or more such lines have been constructed at widely different times.

Effect of Transportation Lines on Initial Subdivision

The roughly digitate outlines of many of the initial subdivision growth patterns for particular periods (Fig. 1) suggest some general correlation between the subdivision growth of Chicago and the location of main transportation routes. This suggested correlation, however, proves to be almost completely limited to the early intercity routes—plank roads and earlier railroads. Local lines, even such early mass transit carriers as horse railways or cable cars, almost always came later than initial subdivision and had little effect upon it in Chicago.

Intercity Routes

Although Chicago's development as an urban unit dates from its designation as a

[6]For a further discussion of the implications of pre-building growth patterns of a city, see J. D. Fellmann, "Urban Intent and Urban Expansion," *Land Economics*, Vol. 31, No. 3, pp. 280–282.

canal town,[7] the canal—begun in 1836 and formally opened in 1848—was a focus for only a part of the total area subdivided before 1856 (Fig. 1). The original town of Chicago was laid out by the canal commissioners at the forks of the Chicago River. Subdivision growth southward and southwestward along the South Branch of the Chicago River and the proposed canal route was particularly rapid. The attraction of the North Branch was less noticeable prior to 1845. On the far South Side of present-day Chicago, initial subdivision centered north of 95th Street on the Calumet River, at one time advocated as the route of the canal.

The canal and river routes were less significant as foci of initial subdivision than were trails. Indian traces and wagon roads north and south along the lake front and westward to the Fox Valley settlements were principal access routes to early Chicago.[8] Post houses, inns, and farms along the trails were forerunners of the extensive subdivision of land prior to 1855 shown on Figure 3. That subdivision was not limited to districts contiguous to the central city. The several isolated, outlying blocks of land subdivided before 1855 are, with few exceptions, correlated with main trails. Although overland movement into Chicago was predominantly from the south, Figure 3 shows a larger area of subdivision on the West Side, initially a less important traffic area. Of course, large blocks of the subdivided territory are undoubtedly not associated with the routes since only about one-half of the 35 square miles of subdivision (exclusive of the central business district) shown on Figure 3 lies within one-half mile of trails.

In 1848, the Galena and Chicago Union Railroad was completed between the Chicago River and the Desplaines River, ten miles to the west, opening a new era in Chicago's

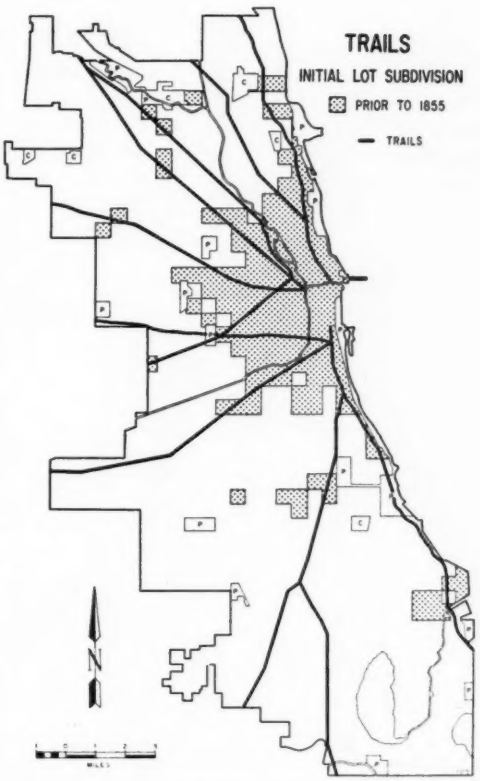

FIG. 3. Early subdivision in relation to overland trails.

transportation history and providing the first of a new series of factors encouraging subdivision. The main period of railroad construction in Chicago covered some forty years —to 1886—and overlapped the development of plank roads and the earliest mass transit facilities, the horse railway lines. The railroads shown on Figure 4—the first important routes penetrating different sections of present-day Chicago—were built primarily in the first half of the period. They passed through land largely unsettled and were considered local mass-transit carriers as well as intercity lines.

More than 110 square miles—over one-half of the present area of corporate Chicago—lies within one-half mile of the railroad lines shown on Figure 4. Despite the early development of railroads in Chicago's history, a considerable part of this associated territory

[7] The long-envisioned canal connecting the Great Lakes and the Mississippi River system moved nearer to realization when the Illinois Legislature of 1829 appointed three Canal Commissioners "to locate the canal, to lay out towns, to sell lots, and to apply the proceeds to the construction of the canal." Quoted in A. T. Andreas, *History of Chicago from the Earliest Period to the Present Time* (Chicago: A. T. Andreas, 1884), Vol. 1, p. 111.

[8] Milo M. Quaife, *Chicago's Highways, Old and New* (Chicago: D. F. Keller, 1923), *passim*.

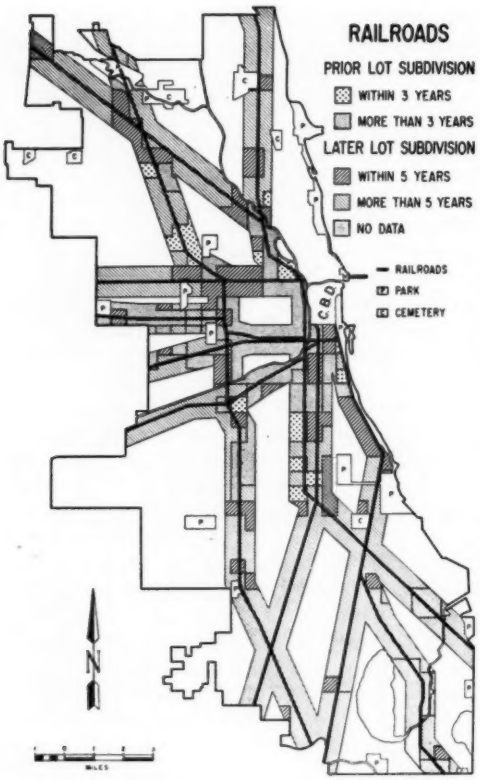

FIG. 4. Subdivision along pre-1886 railroads; subdivision periods correlated with dates of railroad construction.

was subdivided before the lines were laid. On an areal basis, the prior subdivision was almost equally divided between the West and South sides; the North Side was not subdivided until after railroad construction. Of the more than 25 square miles subdivided before railroad building, however, only 1.75 square miles were subdivided in the three years immediately prior to road construction. Only about 2 percent of the entire associated area shown on Figure 4 shows a close relationship between initial subdivision and subsequent railroad construction. On the other hand, 13 percent of the affected area was subdivided within five years of the opening of the mapped routes. Therefore, railroads in Chicago had a greater subsequent than prior effect on land subdivision. In both amount and percentage of subdivision affected immediately, railroads rank as among the most important stimulators of land preparation in Chicago.

It is apparent from Figure 4 that railroad building proposals did not significantly encourage subdivision on the South Side. Only 2.6 percent of the South Side area (the section containing the oldest railroads) was subdivided in the three years before line construction. Nor did railroads bring immediate subdivision; only 8.9 percent of the affected South Side area was subdivided in the five years after railroad construction. The West Side in general contains the more recently constructed roads and other factors affected the area's subdivision. Nearly one-half of the West Side's associated districts were subdivided prior to railroad construction. Nonetheless, one-fifth of the affected area on the West Side was subdivided within 5 years after railroad development—a higher proportion than in any other section of the city. As shown on Figure 4, the North Side has the smallest affected area and practically no prior subdivision; but over 17 percent of the area shown was subdivided within 5 years after development of the single railroad shown.

Between 1848 and 1855 both intercity and local plank roads were rapidly constructed through all sections of Chicago. Available as toll roads to all travelers, they were expected to provide rapid communication with outlying settlements and to solve the problem of moving loads over the wet prairies. Though they soon proved impractical and were quickly replaced by the developing railroad network, plank roads were important in stimulating subdivision. Figure 5 shows the 52 miles of plank roads built within present-day Chicago and the 47 square miles of area associated with those routes. The fact that about 30 percent of these adjacent lands were subdivided within an 8-year period (10 percent within 3 years before road construction, nearly 20 percent within 5 years after) implies that the plank roads were the most important transportation agent affecting initial subdivision. Since in general the time and routes of plank road and railroad construction were not coincident, the effect of plank road development on subdivision may be clearly distinguished.

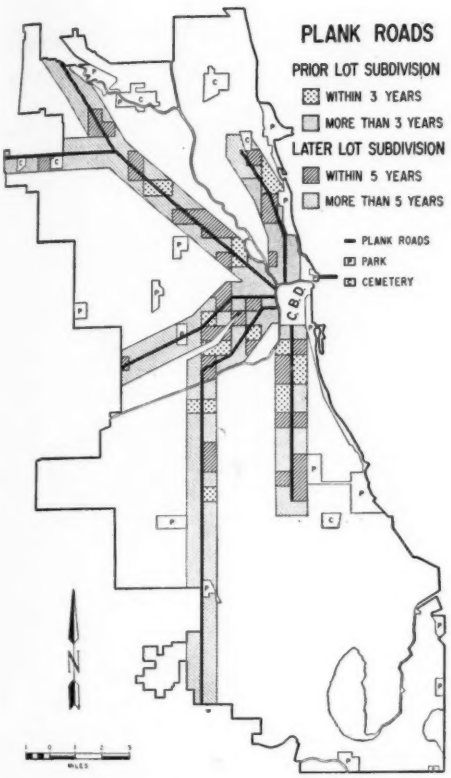

FIG. 5. Initial subdivision near plank roads related to dates of road development.

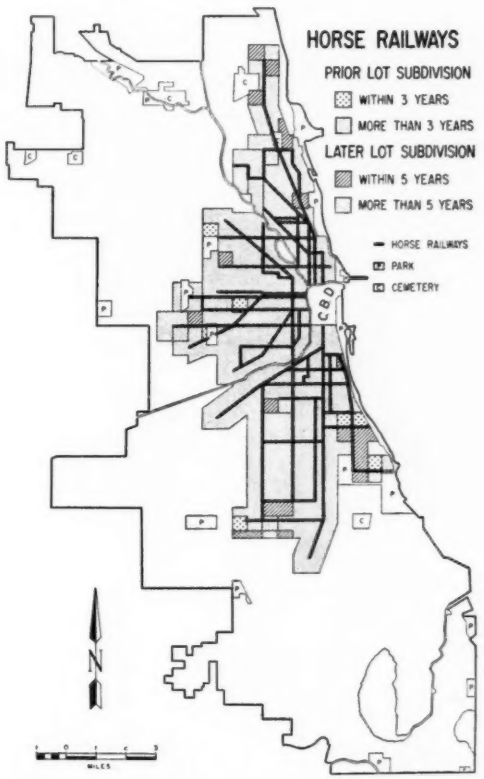

FIG. 6. Horse railway lines and the subdivision of adjacent land.

Local Transport Lines

The horse railways, shown on Figure 6, were the earliest of the heavy-volume mass transit lines. Like the later local transport systems, and unlike the intercity railroads and plank roads, horse railways had only a slight temporal correlation with initial subdivision of land along their routes. However, as the earliest of the extensive local transit systems, horse railways did exert a greater effect on adjacent areas than did the later transit lines.

Horse railway lines were constructed in Chicago between 1859 and 1888. The area within three miles of the periphery of the central business district includes almost all of the early lines—those opened between 1859 and 1870 (Fig. 6). As shown on Figure 1, this same area was largely subdivided before 1855, and the earliest of the horse railway lines inevitably went through territory already subdivided. The extension of the "horse car" lines to the final pattern shown on Figure 6 was in general delayed 15 to 20 years until traffic demand encouraged new lines farther out from the core of the city. That is, horse railways generally followed (by an average of 15 years) rather than preceded subdivision and were not determinants in the developing subdivision pattern of the city. Even in those cases, as in the South Side park area, where a considerable block of subsequent subdivision is shown on Figure 6, the causative action of horse railways is in doubt.[9]

Cable car and elevated railways lines were introduced into Chicago between 1882 and 1908. Since they required already settled areas to make them financially successful,

[9]The horse cars were extended to the lake front park (Jackson Park) in 1867, the same year the park —itself a stimulator of subdivision—was opened.

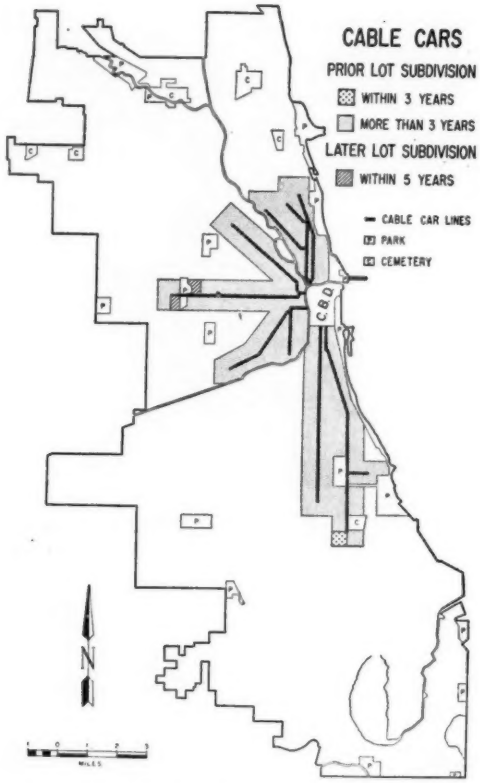

FIG. 7. Subdivision along the cable car lines of Chicago.

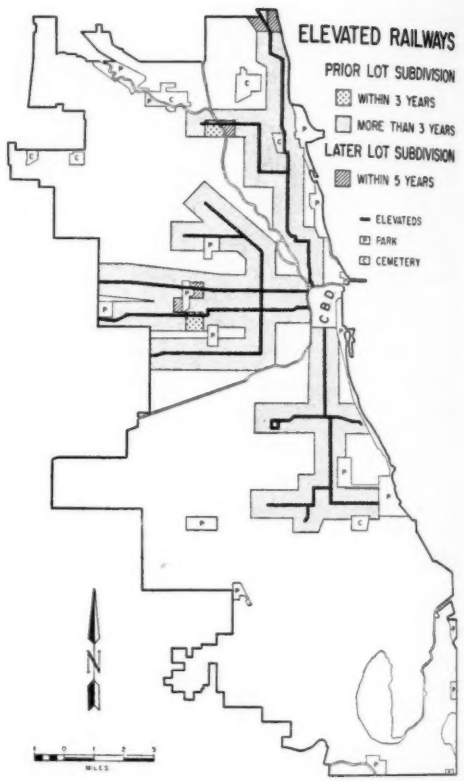

FIG. 8. Subdivision near elevated railways correlated with dates of construction.

neither cable cars nor elevated railways exerted much influence on the subdivision of lands immediately adjacent to their routes.

Chicago at one time had the largest cable car system in America. With the exception of the routes and loops in the central business district, the entire 37.5 miles of line is shown on Figure 7.[10] Only about 28 square miles (13 percent) of the total area of present corporate Chicago was within the zone of influence of the cable car lines. With the exception of the long southern extension, all of the lines are within 5.5 miles of the central business district and therefore within the earliest subdivided and settled area of the city. The entire cable car system was built late in the history of Chicago's expansion—between 1882 and 1893. These dates explain the almost complete previous subdivision of the adjacent area. Even along the last mile of track on each line, the average time lag between subdivision and subsequent cable car line construction was 30 years.

In a like fashion, the elevated railroads came late in Chicago's settlement history and followed rather than preceded subdivision along their routes (Fig. 8). The earliest elevated railway line, the famous "Alley L" on the South Side to 63rd Street, was not erected until 1892. Its entire course, as well as that of later South Side lines constructed after 1900, ran through territories subdivided an average of 25 years before the advent of the lines. The West Side system, next in time of construction, also ran through territories long previously subdivided. The North Side system, not begun until 1900, shows some slight

[10]Data from George W. Hilton, "Cable Railways of Chicago," *Electric Railway Historical Society, Bulletin*, Number 10 (Chicago, 1954).

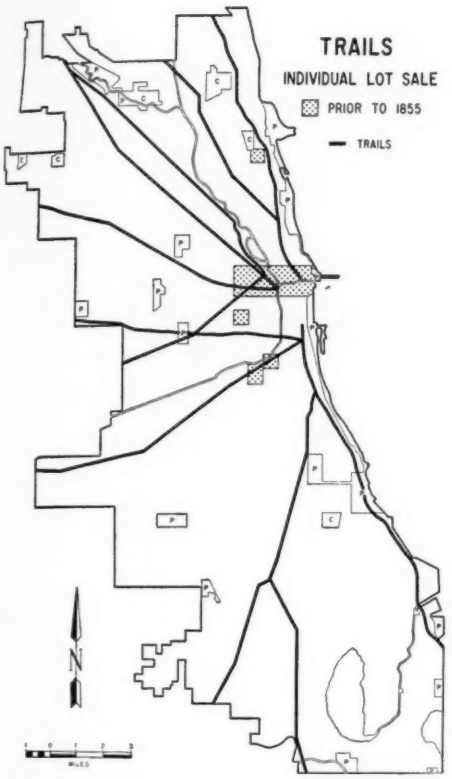

FIG. 9. Pre-1855 lot sales in relation to early Chicago trails.

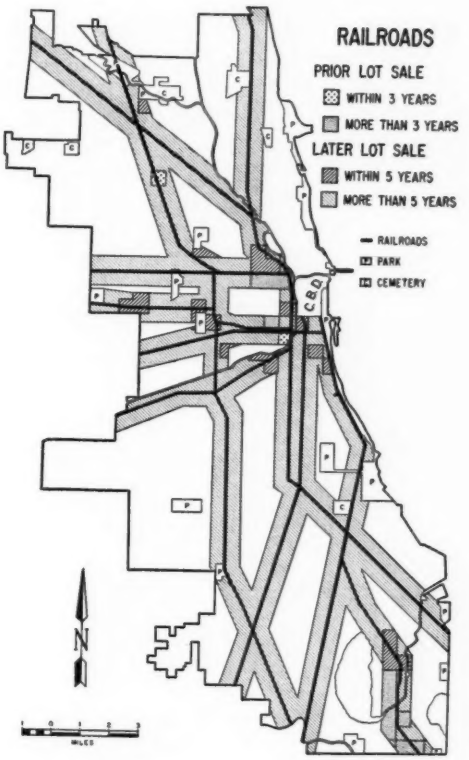

FIG. 10. Lot sales along pre-1886 railroads, correlated with dates of railroad construction.

temporal relationship with subdivision along the last one-half mile of route. But the entire elevated system of Chicago affected the subdivision of only 4 percent of its associated territory.

Effect of Transportation Lines on Individual Lot Sales

The sale of lots to individuals is the final land transaction preparatory to the physical expansion of a city. Individual lot sales in Chicago display a pattern (Fig. 2) based upon the decisions of a great number of individuals responding to a variety of local influences and considerations. In the irregular pattern of individual lot sales there is no suggestion of the digitate outline noted for initial subdivision (Fig. 1). In another way unlike initial subdivision, individual lot sale growth of Chicago is correlated with local mass transit developments, not with the construction of intercity lines.

Intercity Lines

Without exception, intercity lines were unimportant in stimulating lot sales in Chicago. The canal had no immediate effect on lot sales except at Bridgeport, a canal workers' settlement at 25th Street and the South Branch. Equally insignificant was the effect of overland trails (Fig. 9).

Although railroads were greeted with enthusiasm by land subdividers who laid out suburban towns and industrial sites along the rights of way, the lines had practically no influence on individual lot sales. Much of the area through which they passed was then too remote from the central city to attract lot purchasers. At the time the routes shown on Figure 10 entered the city, only about 3 per-

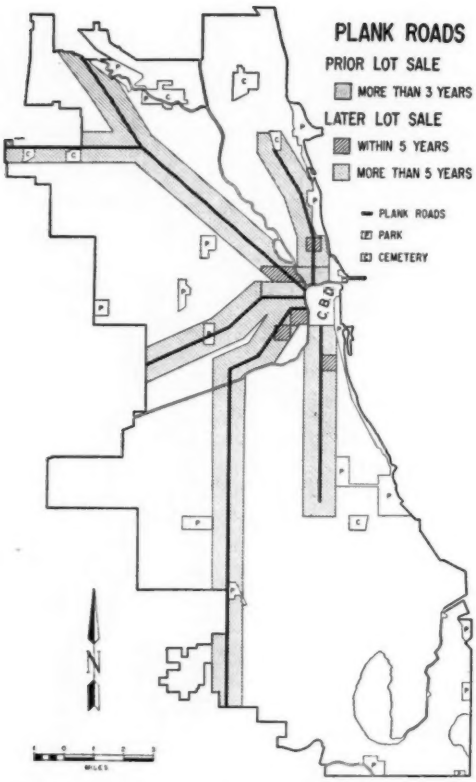

FIG. 11. Lot sales in relation to the development of plank roads.

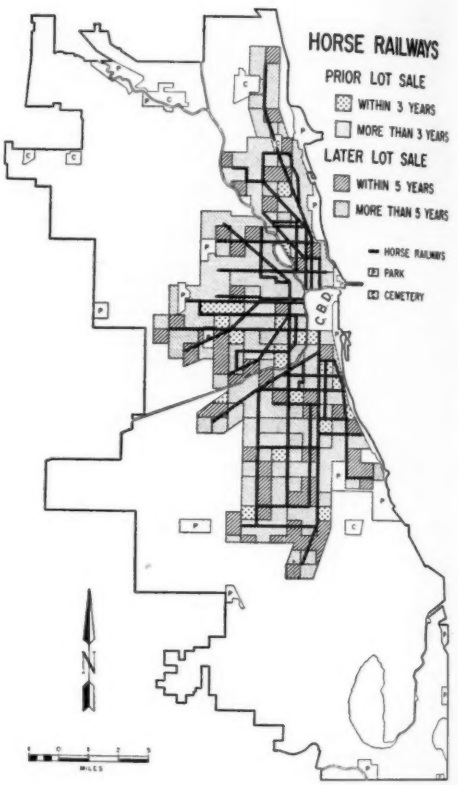

FIG. 12. Lot sales along the horse railway lines of Chicago.

cent of the adjacent area had been sold, and only one-half square mile of that was sold within the 3 years before route construction. Nor did railroads stimulate lot sales. Only isolated quarter sections, mainly in the western part of the present-day city, were sold within the 5 years following railroad construction.

Plank roads were no more effective than the canal, trails, or railroads in encouraging individual lot sales. Of the total affected area of 47 square miles (Fig. 11) a little over 1 square mile had been sold prior to road construction, but these sales were too early to be logically associated with proposals for the roads. Further, only 1.5 square miles were sold within 5 years after plank roads were laid. The remainder of the area within one-half mile of the plank roads was sold more than 5 years later, and even very near the margin of the central business district the average time lag between road construction and individual lot sales was 18 years.

Local Transport Lines

Horse railways provide an example of the relatively close correlation between intracity lines and lot sales patterns in Chicago. As Figure 12 shows, some general correlation between horse railway lines and individual lot sales exists in all sections of the city. Nearly 25 percent of the land adjacent to horse car lines was sold within 5 years after, and another 9 percent within 3 years prior to the construction of those lines. The correlation was particularly close on the South Side where 30 percent of all lots within one-half mile of the horse car lines were sold within 5 years following establishment of those lines. The North Side, on the other hand, showed the lowest proportion of lots sold immedi-

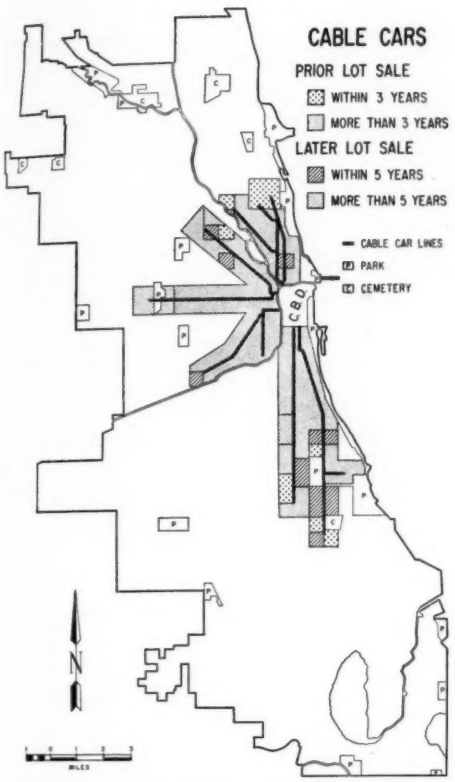

FIG. 13. Lot sales near cable car lines, correlated with dates of line construction.

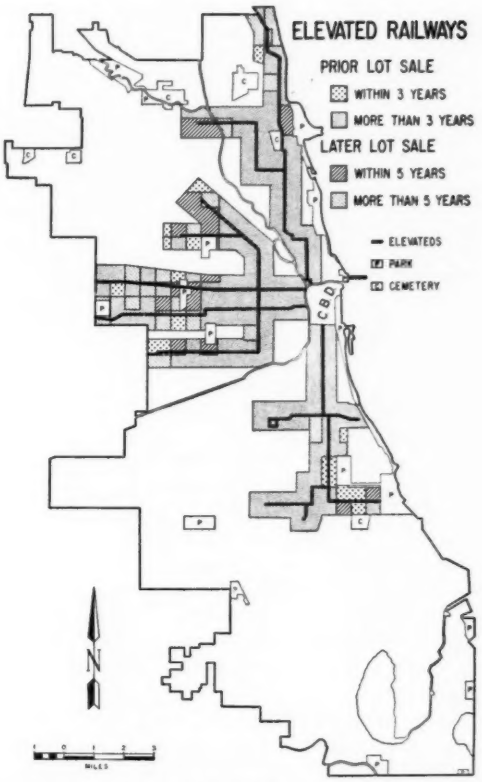

FIG. 14. Lot sales in relation to elevated railway construction in Chicago.

ately before or after the construction of horse railways.

Neither cable car nor elevated railway lines influenced individual lot sales patterns as much as horse railways did. But even these two heavy volume carriers, although coming late in Chicago's expansion, affected lot sales much more than did the intercity carriers.

While the cable car routes did not stimulate initial subdivision (Fig. 7), all of the lines show a temporal relationship to individual lot sales (Fig. 13). Of the total affected area, 10 percent was sold within 3 years prior to, and 12 percent within 5 years following, line construction. The construction of these routes was a well-advertised, long-term project, and knowledge of the availability of mass transit facilities increased the salability of adjacent lands. This is particularly well demonstrated on the South Side, where three separate blocks of land were sold immediately before cable car line construction or extension. All three of these parcels were sold only one year prior to the formal opening of the section of cable car line with which they are associated.

Elevated railways were the least effective mass transit medium influencing individual lot sales. Only 17 percent of adjacent territories were sold within the 3 years before and the 5 years following elevated line construction; most of the adjacent land, as indicated on Figure 14, was sold long before the advent of the "els." In only two localities did elevated railways directly influence lot sales over considerable areas: at the termini of the two lines leading toward the northwestern portion of the city.[11]

[11]Later transit systems—electric street railways, motor buses, subways, etc.—are not considered here because by the time of their introduction and greatest development, subdivision of Chicago was substantially completed.

TABLE 1. – TRANSPORTATION MEDIA: EFFECT ON SUBDIVISION AND LOT SALES IN CHICAGO

Transport medium	Associated area (sq. mi.)	Construction period	Percent of adjacent area affected			
			Subdivision		Sale	
			0-3 yrs. prior	0-5 yrs. later	0-3 yrs. prior	0-5 yrs. later
Plank roads	47.0	1849–55	10.1	18.6	2.6	3.2
Railroads	110.5	1848–86	3.4	13.1	0.4	4.5
Horse railways	57.25	1864–88	3.0	7.8	8.6	24.4
Cable cars	27.75	1882–93	0.9	1.8	9.9	11.7
Elevated railways	50.75	1892–1908	1.0	3.0	6.9	9.8

Summary of the Effect of Transportation Media on Subdivision and Sale

Table 1 summarizes the effect of the various inter- and intracity routes on subdivision and lot sales in Chicago.

The intercity lines—railroads and plank roads—apparently did influence the rate and direction of initial subdivision expansion in Chicago and gave rise to the digitate outlines observed earlier in Figure 1. These same lines, however, had little influence on lot sales. Despite their attractions for the speculative subdivider, the areas through which they passed were too remote for most lot purchasers.

Local mass transit lines were much more effective in localizing lot sales than they were in stimulating initial subdivision. As Table 1 indicates, the earlier lines—particularly horse railways—affected sales patterns on a higher percentage of their adjacent territories than did later mass transit systems. Horse railways passed through more undeveloped territory than did the elevateds or cable cars, and so had a chance to exert a greater influence on the development patterns of the city.

Transportation lines were only one of several potential stimulators of initial subdivision and lot sale in Chicago. Both municipal parks and outlying settlements also played important roles in directing pre-building growth patterns of the present-day city.

EFFECT OF PARKS AND SETTLEMENTS

Municipal parks and outlying settlements had a strong influence on both initial subdivision and individual lot sales. Both settlements and parks stimulated subdivision more than they did lot sales; in both cases, prior activity is a less significant part of the expansion pattern than is subsequent land preparation.

Municipal Parks

Chicago's park system has been credited with being a strong attractive force in directing the physical growth of the city.[12] Parks were similarly important in stimulating pre-building expansion. Of the total of 18.25 square miles of area surrounding the principal municipal parks (Fig. 15), 28 percent

[12]Hoyt, *op. cit.*, pp. 100, 107–108.

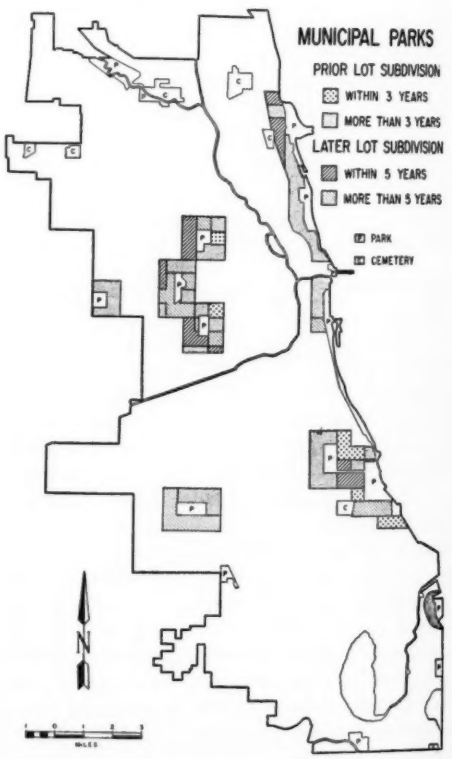

FIG. 15. Initial subdivision in relation to the development of principal municipal parks.

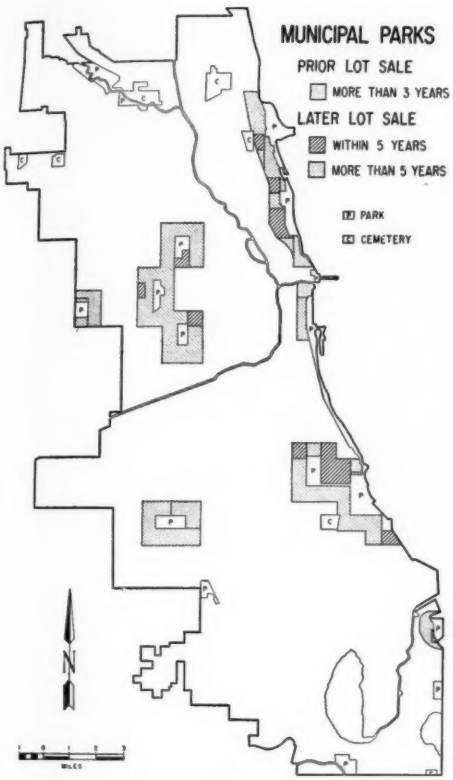

FIG. 16. Lot sales in relation to the development of principal municipal parks.

was directly influenced in subdivision activity within 3 years before and 5 years after the park establishment. Ten percent was subdivided immediately before and 18 percent immediately after park development, making the parks one of the most important single influences on subdivision patterns in Chicago. The affected area on the cityward side of each of the parks was subdivided prior to the establishment of the parks, while the outer margins were subdivided later (Fig. 15).

The municipal parks were only slightly less effective stimulators of individual lot sales activity. Although, as seen in Figure 16, no anticipatory lot purchases were made, 20 percent of the affected area around the principal parks was sold within 5 years after their establishment. Here again we note a tendency for the cityward side to be sold earlier, and the more isolated margins much later.

Settlement Sites[13]

There is a very high temporal correlation between establishment of outlying settlements and immediately subsequent subdivision. As seen in Figure 17, 34 percent of the land areas associated with settlement nuclei was subdivided within 10 years after establishment of the population clusters. Settlement sites appear to have had a greater effect on subdivision growth patterns in Chicago than any other examined feature. However, the relationship between settlements and transportation routes (particularly the courses of the earlier railroads) tends to obscure the true effect of settlement sites alone.

Like the intercity lines with which many of them were associated, settlement nuclei had less influence on individual lot sales patterns than on subdivision. As Figure 18 shows, whatever may be the dates of the initial settlements, essentially all of their affected areas were sold after, rather than before, establishment of the nuclei, and only 13 percent of that adjacent land was sold within 10 years following establishment of the outlying communities.

THE EFFECT OF BOOM PERIODS

Lot subdivision and sales were also greatly influenced by cyclical economic fluctuations. A major portion of the lot subdivision and sale during Chicago's history was concentrated in the relatively few years included in periodic land booms. The speculative aspects of both subdivision and sale during boom periods gave rise to expansion patterns which were only in part related to the stimulators of land preparation discussed above.

Until the mid-1930's, there was almost always an oversupply of subdivided land in Chicago (Table 2). More than one-half of the present-day city was subdivided by 1871; nearly two-thirds by 1885.[14] The principal

[13]In Figures 17 and 18, each early suburban town and unincorporated settlement is considered as the center of an associated area extending one mile in each direction from the settlement. Because of difficulties in precise dating of settlement establishment, the periods of presumed effect have been extended to five years before settlement and ten years after.

[14]Helen C. Monchow, "Seventy Years of Real Estate Subdividing in the Region of Chicago," *Northwestern University Studies in the Social Sciences*, No. 3 (Evanston: Northwestern University, 1939), p. 19.

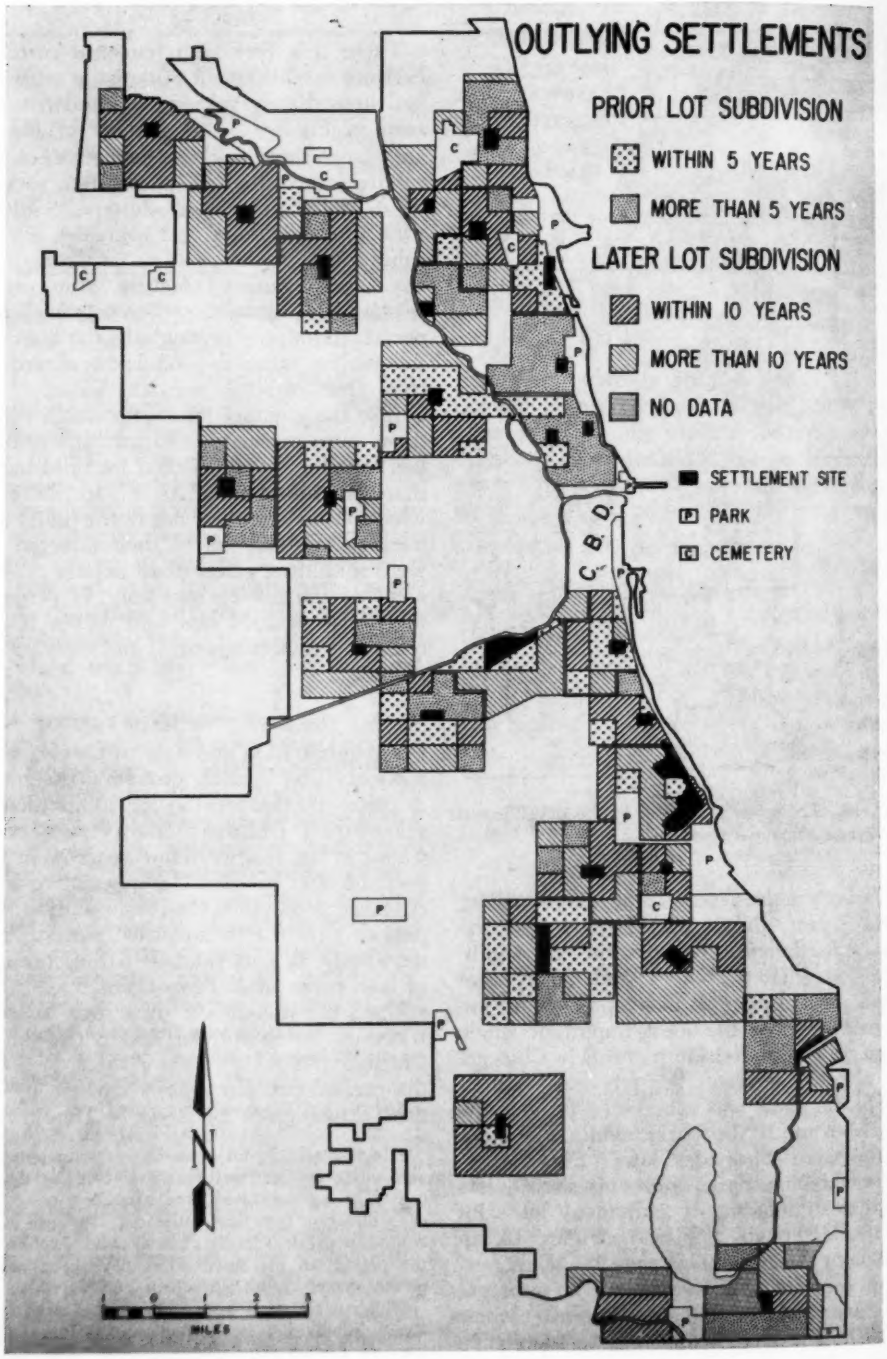

FIG. 17. Subdivision near former outlying settlements in relation to dates of establishment of settlements.

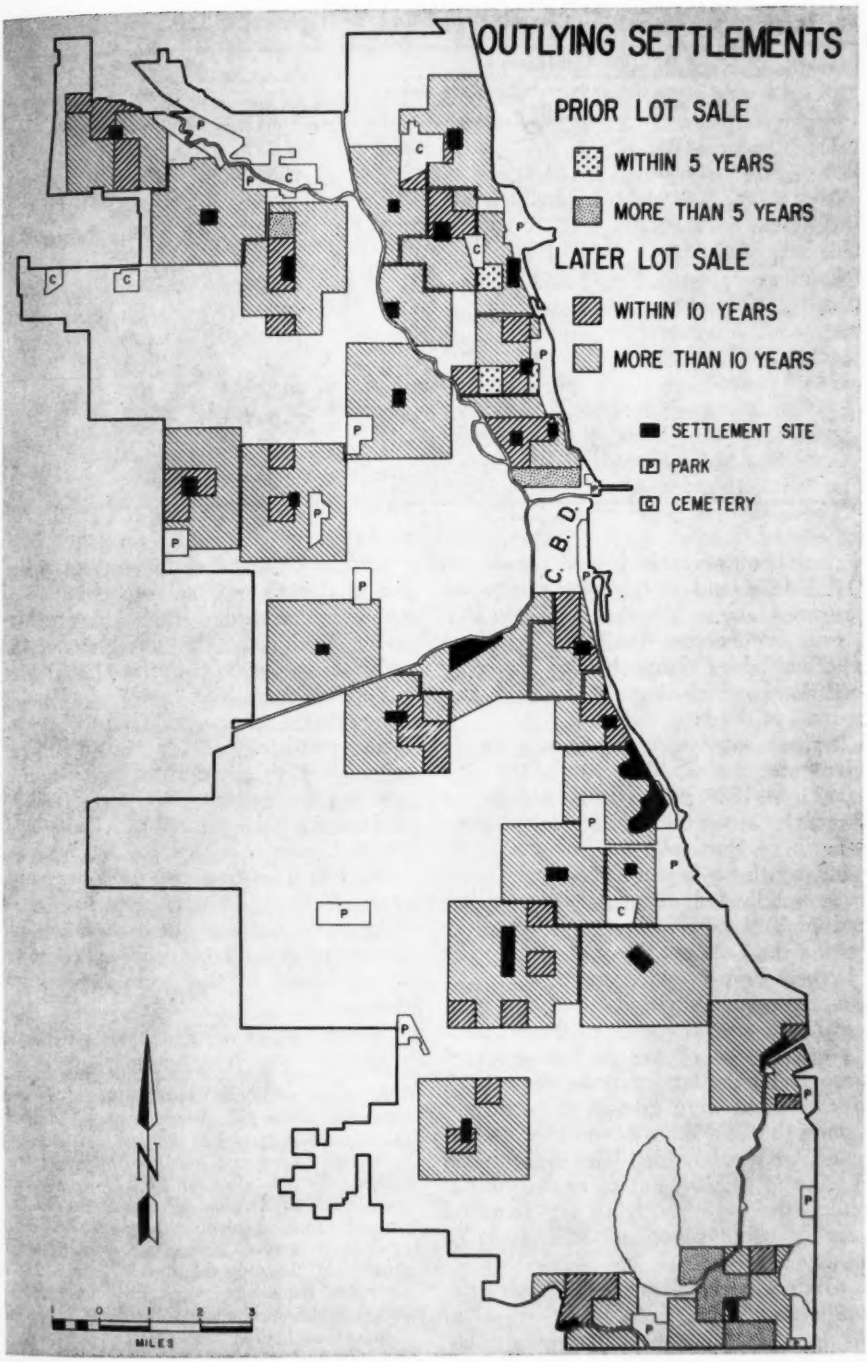

FIG. 18. Lot sales in relation to establishment of former outlying settlements.

TABLE 2. — THE EXTENSION OF LAND PREPARATION IN CHICAGO

Date	Initial subdivision			Individual lot sale		
	Area (sq. mi.)	Percent of city area	Cumulative percent	Area (sq. mi.)	Percent of city area	Cumulative percent
1831–1845	12.00	5.6	5.6	2.75	1.3	1.3
1846–1855	24.50	11.5	17.1	1.50	0.7	2.0
1856–1865	25.75	12.1	29.2	6.75	3.2	5.2
1866–1875	71.00	33.4	62.6	33.50	15.7	20.9
1876–1885	3.50	1.6	64.2	16.50	7.8	28.7
1886–1895	33.00	15.5	79.7	48.50	22.8	51.5
1896–1905	0.75	0.4	80.1	20.00	9.4	60.9
1906–1915	16.75	7.9	88.0	17.75	8.3	69.2
1916–1925	14.75	6.9	94.9	35.00	16.5	85.7
1926–1935	1.00	0.5	95.4	20.25	9.5	95.2
1936–1945	—	—	95.4	2.00	0.9	96.1
1946–1953	—	—	95.4	2.75	1.3	97.4
No data	9.75	4.6	100.0	5.50	2.6	100.0

subdivision booms reached their peaks in 1836, 1856, 1872, and 1890, giving rise to the great areas of new subdivision shown in Figure 1 and summarized in Table 2. These booms often added large blocks of newly prepared land which lay far beyond the settled areas of the city.

The earliest subdivision boom was nearly coincident with the establishment of the city. From 1833 to 1836, with the latter as the peak year, the area around the original town as far north as North Avenue, west to Ashland, and south to beyond Roosevelt Road had been subdivided. Furthermore, outliers of prepared land were to be found far to the south along the Calumet River and far to the north beyond Bryn Mawr Avenue (Fig. 1).

The increase in subdivision activity between 1848 and 1857, with the peak of the boom in 1856, overlaps two of the periods mapped in Figure 1. Of the land added before 1855, the largest blocks were extensions north and south along the lake shore beyond the settled territories. Areas subdivided later in the boom period were in smaller and more discontinuous tracts, the majority lying far removed from earlier subdivisions in all sections of present-day Chicago.

The subdivision boom of 1865–72 was the most important single creator of new urban land in the city. More than 70 square miles, 33 percent of the total area of Chicago, was initially subdivided during this boom period (Table 2).[15] The result was to oversupply the market to such an extent that essentially no new subdivision occurred for nearly twenty years. Within the 1873 city limits of Chicago, only about one-half of the platted lots were occupied; from 1868 to 1873 lots enough for a population of one million had been offered for sale in a city of less than 400,000.[16] The pattern of subdivision in this boom period was not continuous. Territories as far south and north as the present city limits were subdivided, even though separated from built-up areas and from transportation by many miles of empty land. This boom period, through its creation of vast areas of subdivided land, left its imprint on all later subdivision growth and clouds many of the correlations previously discussed.

The boom of 1889–90 was the last great

[15]The boom was not continuous but composed of a series of separately acting influences. The new horse car lines and railroads made lands in their vicinities seem attractive to speculators; the increase in manufacturing and the move of manufacturing to outlying districts after the Civil War encouraged the speculative subdivision of other areas adjacent to new or proposed plants; the parks and boulevards established in 1869–70 created a rash of subdivision activity in their neighborhoods, while the fire of 1871—and the subsequent establishment of fire limits within which no wooden buildings could be constructed—resulted in whole new areas being brought onto the land market as proposed residential districts outside the previously settled sections.

[16]Hoyt, *op. cit.*, p. 109.

concentrated flurry that materially affected Chicago's subdivision growth patterns. When it was over, only 20 percent of the present-day area of Chicago was not subdivided. Figure 1 shows most of this initial subdivision concentrated in the south and southwest sections of the city, most of it not beyond the previous outer limits of subdivision, but rather in the interstices between areas of earlier activity.

During each of the boom periods, the frenzied activities of lot purchasers echoed those of land subdividers.[16] Of the boom of 1836 it was said:

> It did not take long . . . to develop a strong speculative fever, which infected every resident of the town and was caught by every newcomer. . . . Whatever might be the business of a Chicagoan or however profitable it was not considered a full success except it shown an outside profit on lots bought and sold.[17]

In 1856 the story was the same: "The country had again, as in 1837, got in possession of a plethora of currency . . . and another mania for speculative and reckless expenditures ensued. . . . Real estate of course caught the infection. . . ."[18] In 1872, "Adventurers flocked into the city, laid out suppositious [*sic*] plats and sold to people who were [anxious] to get hold of lots, blocks, or acres. . . ."[19] And in 1890, ". . . sales were made so fast that half-a-dozen transfers of contracts to purchase were sometimes made before one deed was recorded."[20]

Despite the number and speed of transactions in all these boom periods, individual lot sales did not keep up with the pace of initial subdivision. While more than 5 percent of Chicago's present area had been subdivided by 1845, only a little over one percent had been sold; after the boom of 1872 the discrepancy was even greater—62 percent of the present city area subdivided, 21 percent sold (Table 2). In fact, not until 1935 was the percentage of subdivision and sale approximately even, and by then nearly all of the city had passed into the possession of individual buyers.

Some sales of individual lots during boom periods were as wildly speculative as was initial subdivision, but the majority were more nearly related to the existent settlement patterns and feasible expansion areas than was initial subdivision. Before the boom of 1836, settlement in Chicago hugged the banks of the river westward to the forks; individual lot sales during the boom (shown in Figure 2) displayed a growth outward from, but closely adhering to, this initial settlement area. Expansion north and south along the lake and in the Calumet River area, so prominent in initial subdivision activity in the same period, was definitely not a part of the individual lot sales pattern. By 1856, physical growth of the city had reached southward along the river to 31st Street, westward to Ashland Avenue, and northward in discontinuous patches to Irving Park Road. Again, this settlement pattern is basic to lot sales expansion between 1846 and 1865 (Fig. 2) and again is vastly different from that shown in Figure 1. By the boom year of 1872, settlement extended almost solidly from Fullerton Avenue south to Pershing Road, and from the lake westward to Ashland Avenue. Wedges of settlement, of course, reached beyond these limits.[21] This boom period added more than twice as much subdivided as sold land to the city (Table 2) and the differences in the two degrees of expansion are apparent from Figures 1 and 2. With the exception of isolated sections near Lake Calumet and the southern city limits and in the extreme northwestern part of Chicago, the lot sales patterns coincide almost exactly with the physical expansion of the city and stand in distinct contrast to the great areas of subdivided lands, particularly in the south and southwestern sections of the city. A similar correspondence between individual lot sales and settlement pattern may be noted for the boom of 1890.

RESUBDIVISION

Not all initial subdivision was immediately followed by individual lot sales—nor was all of it designed for lot sales. The excess of

[16]Andreas, *op. cit.*, I, p. 134. Quoted verbatim.

[17]Everett Chamberlin, *Chicago and Its Suburbs* (Chicago: T. A. Hungerford, 1874), p. 201.

[18]*Real Estate and Building Journal*, May 13, 1876. Quoted in Hoyt, *op. cit.*, p. 118.

[19]Hoyt, *op. cit.*, p. 172.

[20]Extensions were found along the lake to 55th and along State Street to 67th; outliers were found on the Calumet River, near 79th and Cottage Grove, 87th and Halsted, along Madison at Pulaski and Central, at several points along the railroad in the northwestern part of the city and northward along the railroad as far as Bryn Mawr on the North Side.

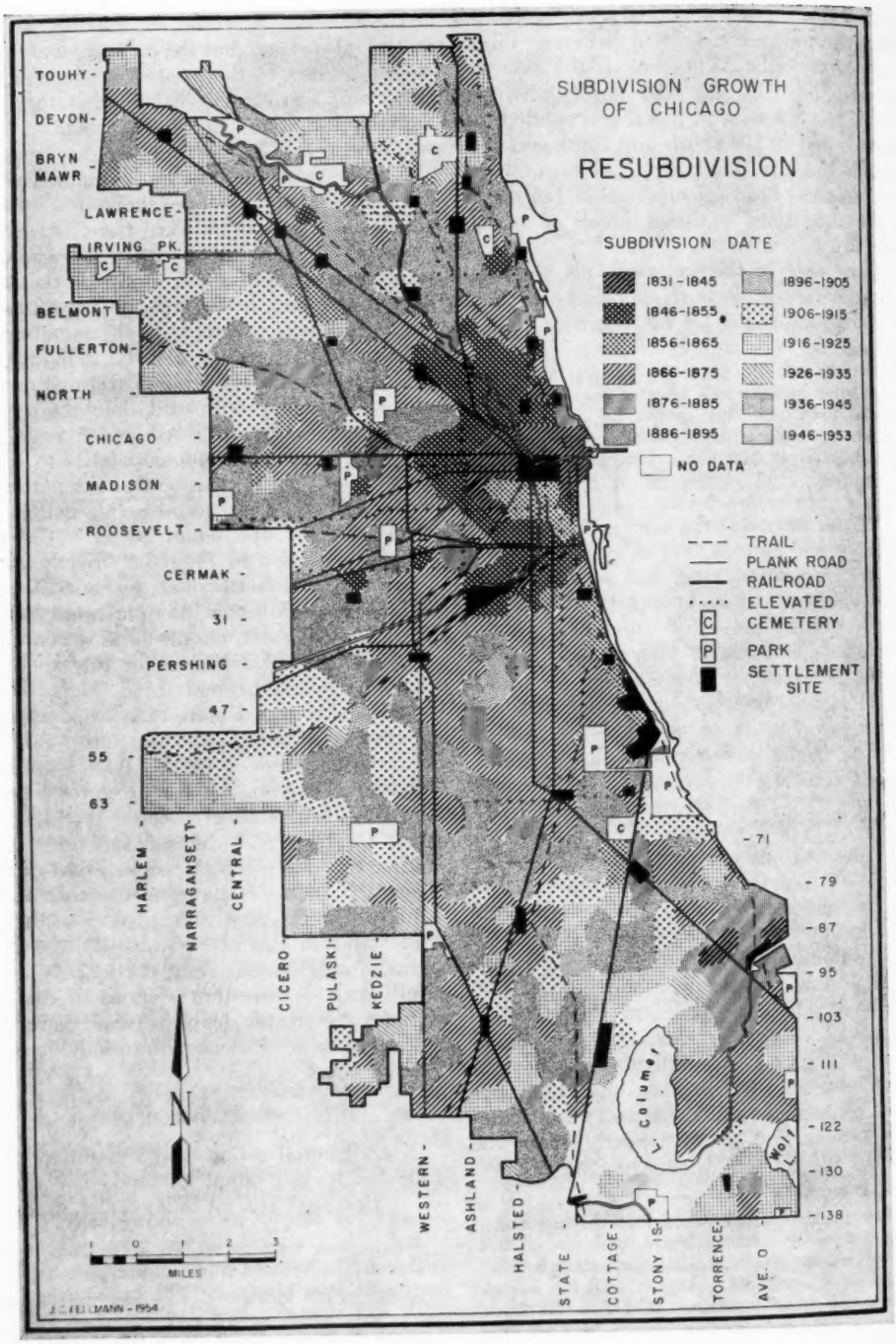

FIG. 19. The pattern of resubdivision in Chicago.

urban lots provided by initial subdividers during boom periods meant that under normal or depressed conditions much of the prepared land was not salable. At later dates and under more favorable market conditions, many of these properties were resubdivided into lots of different size or into lots designed for different types of use to make them more attractive to potential buyers. Some of the initial subdivision shown in Figure 1 refers to assessor's subdivisions—areas divided into lots by the government simply for taxing purposes and not intended for sale. These assessor's lands, subsequently sold, were also resubdivided for urban use. During all the boom periods some nonurban lands were subdivided into acre tracts rather than into city lots and were held by speculators anticipating increments in value; these tracts were later resubdivided for sale when market conditions were deemed favorable.

The patterns of resubdivision and subdivision into lots are shown on Figure 19. In some instances, of course, initial subdivision and subdivision into lots were simultaneous and were quickly followed by sale of the lots to individual purchasers. However, a comparison of Figures 1 and 19 marks out those districts in which a second stage of land preparation occurred. Principal areas of resubdivision coincide with some of the great tracts initially subdivided during the various land booms. Striking examples are to be found in those areas subdivided during the booms of 1836 and the mid-1850's and adjacent to the central business district.

In general, resubdivision of lands occurred in the next "boom" after initial subdivision. South of 31st Street, areas subdivided during the boom of 1856 were resubdivided between 1866 and 1872. Throughout the south and southwestern areas of Chicago, lands subdivided during the peak of the post-Civil War boom period were resubdivided in 1890 (although some were not handled until the last, and least effectual, Chicago boom of 1926). Much the same sequence is found in the North Side. Centering on Kedzie north of Chicago Avenue is a large strip of land subdivided during 1866–72; most of this area was resubdivided during the boom of 1890, though some was held even later.

Even resubdivision did not make all lands immediately acceptable to individual lot purchasers. Comparison of Figures 2 and 19 will indicate the delays in acceptance that occurred even after the new stage of land preparation.

TIME LAGS

The patterns of delay between initial subdivision, resubdivision, and individual lot sale are shown in Figures 20, 21, and 22. Because of the great variety of local conditions affecting different areas of the city—extent of settlement, transportation lines, boom periods, etc.—there are no clear-cut citywide patterns of time lag. Nevertheless, each of the three mapped time lags—subdivision to lot sale, subdivision to resubdivision, and resubdivision to lot sale—indicates that despite the delays in acceptance previously noted, the largest single block of territory in each case passed from one stage of preparation to the next within 10 years.

Naturally, the greatest delays are to be found between initial subdivision and individual lot sale—the first and last stages of conversion of nonurban land to urban use (Fig. 20). Only 32 percent of the city area made this change in status within 10 years, while 27 per cent experienced a time lag of at least 30 years. All sections of Chicago have tracts of land which lay unsold for 30 or more years.

Nearly one-half (47 percent) of the total area of Chicago was resubdivided or subdivided into lots within 10 years following initial subdivision (Fig. 21). Even discounting those areas in which initial subdivision and subdivision into lots were simultaneous (1 percent of the total area), it is evident that land preparation advanced from one stage to another very quickly over much of the city, particularly southward from the central business district along the lake front, and in the southwestern areas of Chicago. Only 14 percent of the city took 30 or more years to pass from initial subdivision to resubdivision.

Resubdivision is the last stage of land preparation prior to individual lot sales, and nearly 60 percent of Chicago passed from resubdivision to individual ownership within 10 years (Fig. 22). Only 6 percent of the city's area experienced a delay of 30 or more years between these two stages of land activity.

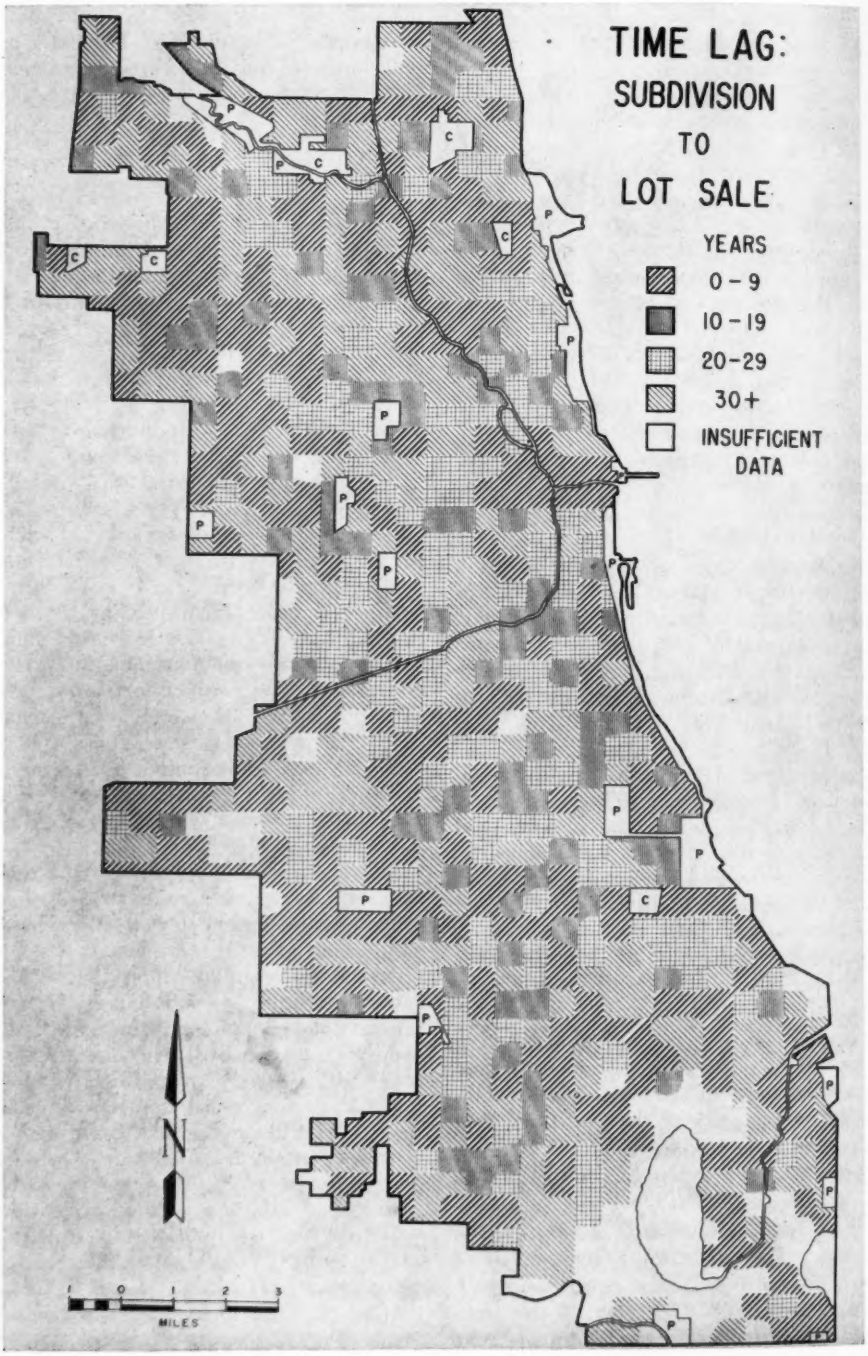

FIG. 20. The pattern of delay between initial subdivision and individual lot sales.

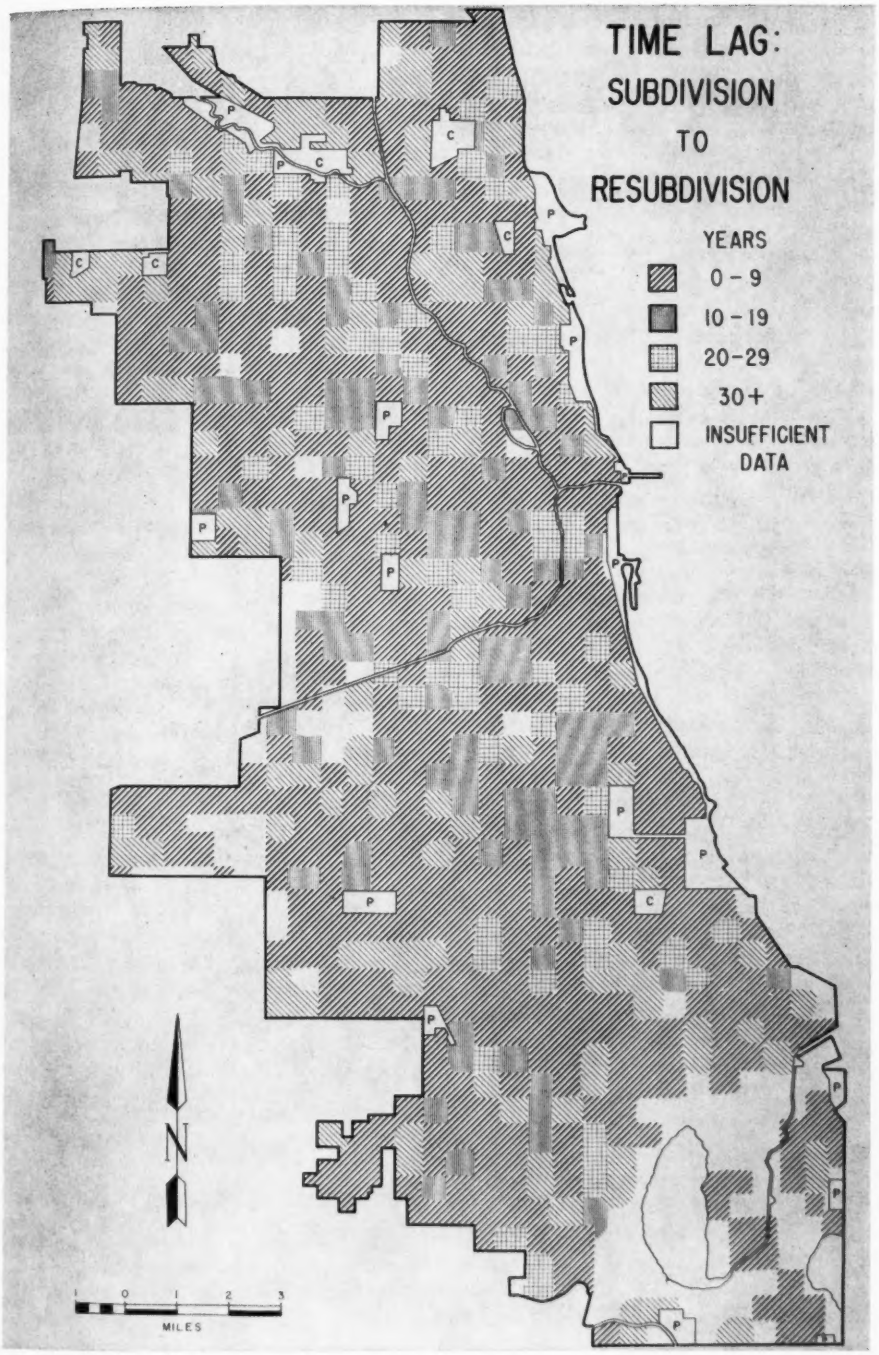

FIG. 21. The pattern of delay between initial subdivision and resubdivision.

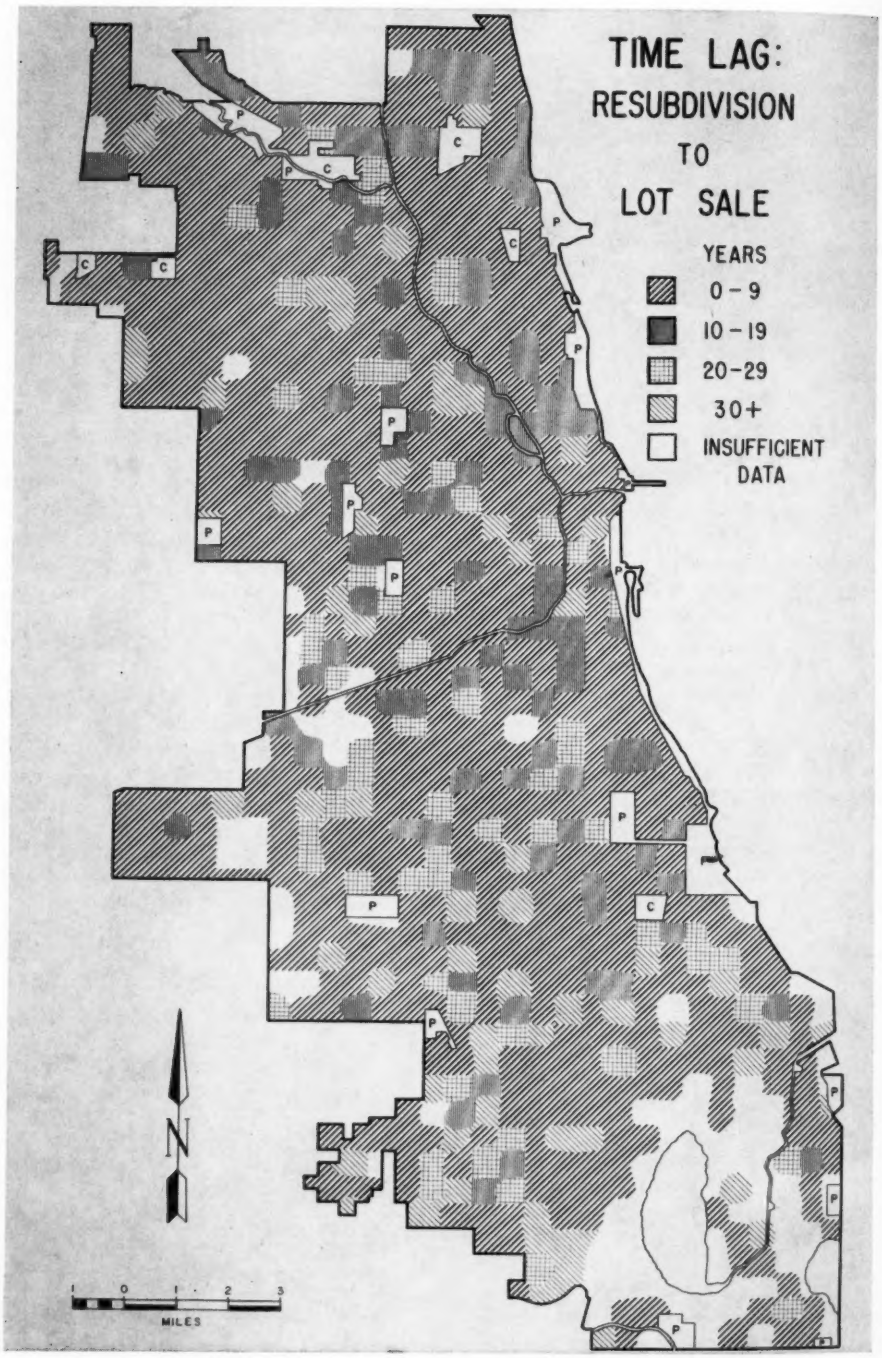

FIG. 22. The pattern of delay between resubdivision and individual lot sales.

SUBDIVISION, SALE, AND URBAN GROWTH THEORIES

Initial subdivision, resubdivision, and individual lot sales are the necessary forerunners of the physical expansion of cities. It does not follow, however, that these introductory phases of urban development exhibit regular patterns of growth similar to those hypothesized for the spread of the built-up area. In Chicago the effects of land booms and presumed local advantages in areas away from the built-up city more seriously affected the patterns of subdivision and sales than they did the patterns of physical expansion.[22]

Theories of physical urban growth emphasize the importance of the original core of the city, of the main traffic arteries at different periods, and of the outlying settlements in giving form and direction to the patterns of expansion. These same elements are recognizable in patterns of pre-building growth. In theory, patterns of individual lot sales, as the last stage of land development prior to building, should most clearly demonstrate the relative importance of the various attractive agents affecting expansion of the built-up area. In practice, the expansion patterns of individual lot sales are less easily explained in theoretical terms than are the patterns of either initial subdivision or resubdivision.

The dominant elements of the concentric circle,[23] sector,[24] and multiple nuclei[25] theories of urban growth are most easily recognized in the pattern of initial subdivision of Chicago (Fig. 1). Around the original town at the fork of the Chicago River spread rings of subdivision—regular and continuous during the early periods of development, interrupted and irregular during the later stages. The margins of the innermost growth circle are not smooth but elongated into wedges or sectors that project beyond the main body of subdivided land. North and south are extensions along the lake front; to the northwest and southwest plank roads and trails, and to the west plank roads and the earliest of Chicago's railroads were marked out by wedges of subdivision before 1855. Outliers of subdivision focusing on settlement nuclei are found in both the earliest years of land preparation and after 1856 when railroad suburban towns became common. The Hyde Park–Kenwood area (lake front and 47th Street) developed around the suburban service of the Illinois Central after 1857; Grand Crossing (approximately 79th and Stony Island Avenue) developed in 1857 shortly after the Michigan Southern crossed the Illinois Central at that point; in the northwestern section, the Chicago, St. Paul and Fond du Lac Railroad, constructed in 1854, gave rise to Jefferson Park (near Lawrence and Central).

Although there are these recognizable accordances with the principal physical growth theories, only a portion of Chicago's initial subdivision growth can be related to them. After 1865, much less coincidence between accepted growth theories and actual expansion patterns can be recognized in Figure 1. The post-Civil War boom resulted in the subdivision of large areas, many of which were not apparently related to any of the theoretical controls of urban growth. This boom period ended the earlier, more regular expansion of Chicago and forced later initial subdividers to work the only lands still untouched, whether or not those remaining lands were in the next outer zone beyond existing subdivision, or were associated with transportation lines or outlying settlements.

The pattern of expansion through individual lot sales in Chicago, though the final stage of land preparation prior to building, shows least clearly the traditional forms of physical urban growth. There is no series of concentric circles outward from the original urban core (Fig. 2). There is a suggestion of sector advance only southward along the lake front and the Illinois Central (1856–65) and along State Street (1866–75), and northward along the lake (1876–85). The outlying settlements seem to have served as the main foci of urban expansion and the "multiple nuclei" theory perhaps best describes this phase of Chicago's

[22]Patterns of physical growth of Chicago, the final stage in the development of a city, are not investigated in this study.

[23]E. W. Burgess, "The Growth of the City," in *The City*, by R. E. Park, E. W. Burgess, and R. D. MacKenzie, eds. (Chicago: University of Chicago Press, 1925), pp. 47–62.

[24]U. S. Federal Housing Administration, "The Structure and Growth of Residential Neighborhoods in American Cities," by Homer Hoyt (Washington: Government Printing Office, 1939).

[25]C. D. Harris and E. L. Ullman, "The Nature of Cities," *Annals American Academy of Political and Social Science*, 1945, pp. 14–16.

pre-building expansion. The majority of the outlying settlements shown in Figure 2 are surrounded or adjoined by lands sold before other lands in the same area: Austin (Central Avenue between Chicago and Madison), Englewood (63rd and State), and Irving Park (Irving Park Road and Pulaski) are examples.

Resubdivision or subdivision to lots (Fig. 19), on the other hand, shows more evidence of concentric circle and sector growth than it does of expansion around outlying nuclei. The original town forms the center of a series of four fairly definite arcs of resubdivision. The inner zone of land resubdivided between 1831 and 1845 is partially broken to the south but is adjoined by a continuous belt prepared between 1846 and 1855. Next outward lies an almost continuous belt of resubdivision that occurred between 1866 and 1875. Land subdivided into lots or resubdivided between 1856 and 1865 is almost excluded from its proper place as the third circle by this later period of resubdivision. The last clearly recognizable circle, though not continuous, is composed of areas resubdivided between 1886 and 1895. This outermost ring is the least regular of all, and is succeeded on its margin by small, discontinuous areas of various resubdivision dates. Wedges or sectors of land of similar resubdivision date are also recognizable in Figure 19—north and south along the lake shore, south along State Street, and westward along the Galena and Chicago Union Railroad (between Chicago and Madison Avenues).

SUMMARY

This paper analyzes the pre-building growth patterns of Chicago. The areal differences in rate and extent of growth through initial subdivision, resubdivision, and individual lot sales are related to the differential attractions of transportation lines, parks, and settlement nuclei, and to the effect of land booms.

Temporal comparisons are made to show the effect of these areal and historical elements on initial subdivision and lot sales patterns. Those comparisons indicate striking differences in the effect of these elements on land preparation. While intercity transportation lines exerted considerable influence on patterns of initial subdivision, they were ineffective in stimulating individual lot sales. Local mass transit lines, on the other hand, almost always came later than initial subdivision in Chicago, but were closely correlated with the timing and direction of individual lot sales. Both municipal parks and outlying settlement nuclei stimulated initial subdivision more than individual lot sales. The great land booms of the 19th century interrupted the regular outward expansion of Chicago through gradual initial subdivision and individual lot sales, and disrupted the close temporal correlations that might otherwise have developed between these growth patterns and transport lines, parks, and settlements. Indiscriminate subdivision and lot sales by speculators added areas of prepared land that the growing city was not able to utilize immediately. Since the newly added lands were frequently not related to the existing transportation net or settled areas, a prolonged time lag occurred between initial subdivision, resubdivision, and lot sales.

Pre-building expansion patterns in Chicago are only partly similar to those theorized as typical of the physical growth of cities. The pattern of initial subdivision contains elements of the concentric circle, sector, and multiple nuclei hypotheses; settlement nuclei are more recognizable than circles or sectors in the expansion pattern of individual lot sales; concentric circle and sector growth are more a part of resubdivision patterns than are outlying nuclei. In all pre-building growth patterns the areas farthest removed from the original town show fewest correlations with accepted physical growth theories.

STATISTICAL TESTING OF REGIONAL BOUNDARIES

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REGIONAL METHODOLOGY

THE organization of the surface of the earth into spatial units having stated levels of difference in specific characteristics is the aim of regional geography. From a methodological viewpoint the procedures employed in regionalization by geographers and sociologists fall into two categories:

1. Observational-descriptive
2. Observational-relational

According to the first approach, which is purely empirical, physical or socioeconomic data are collected by means of field traverses or assembled from census units. Boundaries are established to separate regions where noticeable changes occur. The raw data may be manipulated statistically to develop simple or multiple indices. The regions are then described in terms of the same values used to delimit them.

Using this method geographers have delimited agricultural, manufacturing, and ethnic regions.[1] In general, the regional studies of sociologists have included several socioeconomic factors derived from county census data which were statistically treated to construct indices. In addition to the construction of simple and multiple indices, factor analysis involving latitude and longitude and correlation analysis techniques were also used.[2]

In the second method, which combines empirical and hypothetical studies, regional boundaries are based on earth features, especially physiography and climate, and other data are assembled according to the resultant areal patterns. This approach rests upon the hypothesis of a relationship between the features of the natural environment used to delimit the area and the physical and socioeconomic properties of the regions. This is the method which is widely used in regional geography textbooks.

An important methodological distinction between the two procedures derives from the difference in the information used to draw the boundary lines and the information used to describe the regions. Simple observational-descriptive procedures employ the same data for both. Observational-relational procedures employ one set of observations to draw the lines and another set to describe the regions. There is thus the implication of a relationship between the data used to establish the regional frame and the areal dispersion within that frame of the data which describe the regional properties. This hypothesis can be tested statistically by appropriate techniques, and the validity of the regional pattern can be objectively accepted or rejected.

Both methods are used widely in regional analysis. However, the observational-relational procedure permits the use of statistical testing to validate the regional structure. This is possible because there is an independence between the two sets of observations: one is used to set up the regions; the other is used to describe them. The investigator thus is able to ascertain if they are related in other than a chance manner.

In this study the areal relationships examined refer to geologic, physiographic, soil, land use, type of farm, and population group regions. Unit areas are established according to physiographic and geologic observations. From these areas data on soils, land use, type of farm, and population groups are collected. If the physiographic and geologic bases of separating the areas from each other are meaningful, the investigator can expect the related

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[1] P. E. James and C. F. Jones, eds., *American Geography, Inventory and Prospect* (Syracuse University Press, 1954). See especially Chap. 2 for extensive bibliography.

[2] D. J. Bogue, "State Economic Areas," *U. S. Bureau of the Census* (Washington, D. C., 1951); C. L. Gregory, "Advanced Techniques in the Delineation of Rural Regions," *Rural Sociology*, Vol. 14 (1949), p. 59; C. E. Lively and C. L. Gregory, "Rural Social Areas in Missouri," *University of Missouri Agricultural Experiment Station Research Bulletin 414* (1948); M. J. Hagood, "Statistical Methods for Delineation of Regions Applied to Data on Agriculture and Population," *Social Forces*, Vol. 21 (1943), p. 287; M. J. Hagood, D. Danilevsky, and C. Blum, "An Examination of the Use of Factor Analysis in the Problem of Subregional Delineation," *Rural Sociology*, Vol. 6 (1941), p. 216; A. R. Mangus, "Rural Regions of the United States," *WPA* (Washington, D. C., 1940).

data on soils, land use, type of farm, and population groups collected from each of these areas to show a response to the spatial frame by exhibiting nonhomogeneous areal distributions. The purpose of the statistical analysis is to determine whether or not the observations collected from each of the unit areas show nonhomogeneous distributions which one could expect by chance sampling.

The following example, perhaps, will make this clear: An area of rough topography developed on certain geologic formations is observed in the field and separated as a unit from a larger area. Geology and topography are related to soils; hence soil acreage data can be expected to show a response. Statistical testing will indicate whether or not it does as compared to other unit areas, and whether or not these observed unit area differences in soils are too great to be attributed to chance. Land use and type of farm are related to geology, topography, and soils. Do they show this relationship when compared to other unit areas? Population groups also are related to type of farm and land use. In an area undesirable for farming, as this example, will there be a concentration of that population group which is lowest on the social scale because this land is available to them and better land is not?

Statistical testing will answer these questions. We cannot rely alone on simple inspection of the field observations on soils, type of farm, land use, and population groups to decide whether the areal frame does result in regions which "really" differ in these properties, for what we have observed may have been due to chance. Statistical testing thus will enable the investigator to validate the boundary lines objectively by employing the concept of statistical significance, instead of relying on arbitrarily selected quantitative differences. Differences in observed values between unit areas are not significant if they may be due to chance. When the results of the test show that the observed differences may be due to chance, the hypothesis is rejected.

CONSTRUCTING THE REGIONAL PATTERN

Detailed field work for this sample study was done in Salem County, New Jersey. Salem County is located on the Middle Atlantic Coastal Plain in the extreme southwestern corner of New Jersey, bordering the Delaware River where it empties into Delaware Bay. The coastal plain of Salem County is formed of glauconitic and nonglauconitic beds of clay, silt, sand, and gravel of upper Cretaceous, Tertiary, and Quaternary ages in varying states of cementation. These strata lap up on the uplands to the west and on each other, dipping southeasterly toward the coast. Differential erosion has resulted in well-defined outcrops of the beds, which strike in a northeast-southwest direction, forming a series of roughly parallel belts. Collectively these landform features are known as a maturely dissected, belted coastal plain whose geomorphic elements are a level Inner Lowland, a dissected Cuesta, and a gentle Backslope.

The Lowland, bordering the Delaware River, has developed on the easily eroded silts and clays of upper Cretaceous and lower Tertiary age. Overlying these beds is a discontinuous mantle of Quaternary deposits of sand. Toward the east the Lowland gradually merges into the Cuesta, which lies about 100 feet above it. The Cuesta owes its prominence to less erodible sandy upper Tertiary beds or to a Quaternary cap rock of iron-cemented sand or gravel. Detailed lithology in the Cuesta is very complex. The beds of sand are of varying thickness, often resting on plastic clay; in places they have been removed entirely. On the gently dipping slopes of the beds which form the Cuesta, a relatively undissected surface has developed. This is the Backslope which has formed on upper Tertiary formations to the west, and on iron-cemented Quaternary beds to the east.[3]

Along the borders of the county that front on the Delaware River and Delaware Bay, and inland paralleling the major streams, freshly eroded material is being laid down in broad tidal marshes. These deposits are classified as Recent in age.

The locational patterns and characteristics of these geologic strata are the basic internal variants in the physical structure of Salem

[3] J. Volney Lewis and Henry B. Kummel, "The Geology of New Jersey" (revised by Henry B. Kummel), *Bulletin 50, Geologic Series* (1940); "Geologic Map of New Jersey" (Lewis and Kummel, revised by Kummel, 1931); R. D. Salisbury, "Physical Geography of New Jersey," *New Jersey Geologic Survey*, Vol. IV (1895).

County. As the boundary lines of the various deposits are observable in the field, they can be used to organize the space of the county into physical regions. Some of the geologic strata were divided into lithologic facies in order to obtain a more accurate representation of the physical detail.

The procedure for regionalizing the county may be summarized as follows:

1. Field mapping of the Lowland, Cuesta, and Backslope according to their observed physiographic expressions.
2. Subdivision of the three major regions by mapping of the local geology. Since available geologic maps were on too small a scale to show sufficient physical detail, they were supplemented by a breakdown of the formations into various facies according to the presence of glauconite, the degree and character of cementation, uniformity of distribution, gross textural characteristics, and also according to the microtopography and immediate subsurface geology.
3. Mapping out the tidal marsh area on the basis of vegetation and water lines.

This procedure resulted in the delimitation of the county into the nine following regions:

I. *Inner Lowland*

- A. Level area of light textured glauconitic and nonglauconitic material associated with the Cape May fm.; Quaternary, underlain by Magothy and Raritan, and Merchantville fms.; upper Cretaceous.
- B. Level area with some relief along the streams of heavy textured glauconitic and nonglauconitic material associated with Woodbury, Marshalltown, and Mt. Laurel and Wenonah fms.; upper Cretaceous, and Hornerstown and Vincentown fms.; lower Tertiary.
- C. Level to slightly undulating area of mixed textured nonglauconitic material associated with the Cape May fm.; Quaternary and Kirkwood fm.; Tertiary, in places underlain by the clayey substratum of the latter.

II. *Cuesta*

- A. Undulating area of nonglauconitic sandy material associated with a sand facies of the Cohansey fm.; upper Tertiary, with hilltops of indurated Bridgeton fm.; Quaternary.
- B. Undulating area of glauconitic and nonglauconitic heavy textured material associated with the Kirkwood and Vincentown fms.; Tertiary, with an intermixture of Cohansey fm.; upper Tertiary, and Bridgeton and Pensauken fms.; Quaternary.

III. *Backslope*

- A. Flat to level area of nonglauconitic and uniformly fine textured material associated with a silty facies of the Cohansey fm.; upper Tertiary, and low divides of the Bridgeton fm.; lower Quaternary.
- B. Gently sloping to level area of medium textured nonglauconitic material associated with a broad undissected surface of the iron-cemented Bridgeton fm.; Quaternary.
- C. Gently sloping area of sandy textured nonglauconitic material associated with a sandy facies of the Cohansey fm.; upper Tertiary and Cape May fm.; Quaternary.

IV. *Tidal Marsh*

Broad flat areas of poor drainage subject to the daily overflow of fresh or salt water caused by tidal movement, generally heavy textured and classified as Recent in age.

The location of each of the regions is shown in Figure 1, an uncontrolled photomosaic. The areal organization of the county thus obtained constitutes a hypothesis of regionalization which states that each of the regions differs from the others in selected physical and cultural properties. If sample data are collected from the regions this hypothesis can be evaluated statistically.

STATISTICAL TESTING OF THE REGIONS[4]

The statistical procedure rests upon the assumption of an expected relation between the physiography and geology used to set up the

[4]I wish to acknowledge the helpful suggestions on statistical procedures by the following: Professor S. B. Richmond, Graduate School of Business, Columbia University; Professor A. Birnbaum, Department of Mathematical Statistics, Columbia University; Mr. W. I. Lourie, Jr., biostatistician, U. S. Public Health Service.

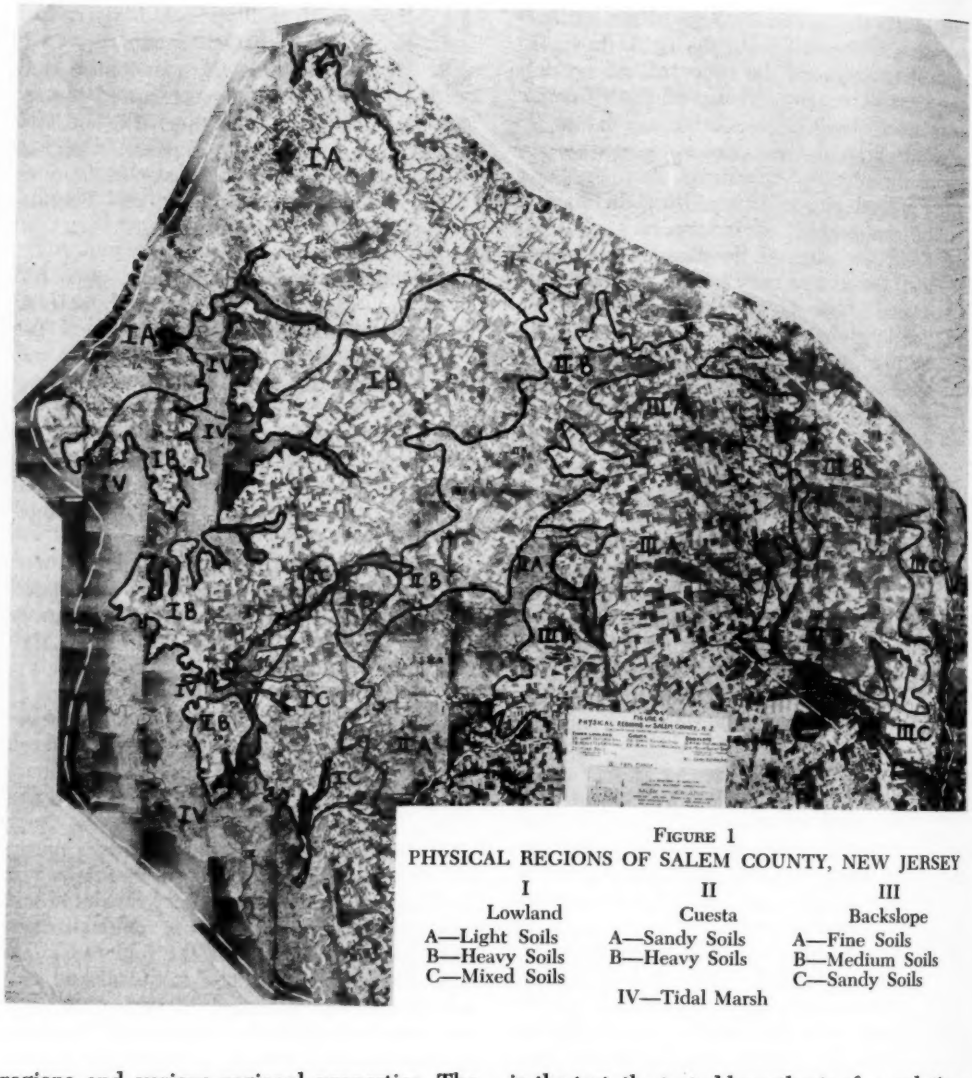

FIGURE 1
PHYSICAL REGIONS OF SALEM COUNTY, NEW JERSEY

I	II	III
Lowland	Cuesta	Backslope
A—Light Soils	A—Sandy Soils	A—Fine Soils
B—Heavy Soils	B—Heavy Soils	B—Medium Soils
C—Mixed Soils		C—Sandy Soils

IV—Tidal Marsh

regions and various regional properties. The chi square test was used. In this test the frequency distribution of observed field data from each region is compared to an expected theoretical distribution in each of the regions. The expected values are calculated under the assumption that no relationship exists between the regions and the test data. This is the null hypothesis, which is actually tested in chi square. If the difference between the two distributions exceeds a critical chi square value which is dependent on the number of degrees of freedom and the level of probability used in the test, the tested hypothesis of no relationship between the regional pattern and the tested data is rejected. The remaining alternative is to accept the regional hypothesis. If the difference between the two distributions is less than the critical chi square value, the null hypothesis is accepted, for the regional differences in the data observed in the field, real as they are, may have been due to chance sampling. In such a situation the spatial patterns that have been set up are rejected because the various areas do not differ significantly in the tested properties. The investi-

gator is on safe grounds in concluding that the bases of the regional organization, in this instance geology and physiography, do not provide any insight in the way the tested properties distribute themselves over the landscape.

Chi Square as a Tool for Regional Analysis

Chi square is an appropriate tool for regional analysis. In regional analysis we wish to ascertain if an association exists between the spatial frame, which is the way the surface of the earth has been partitioned, and the areal dispersion of specific properties in this frame. Nonquantitative (the regional structure) and quantitative (field observations) characteristics are being related. We are interested in the association between a single trait and the regional structure as a whole, and in the association between parts of the regional structure and single traits. In regional studies it is important to set up only those areas which differ from each other. The heart of the matter is the meaning of "differ." In statistical testing probability and chance replace absolute quantities. Samples drawn from the same population will differ. When dealing with samples drawn from unknown populations we need to know if the sample differences are large enough to indicate that the samples were drawn from the same or different populations. By regarding the observations taken from each region as samples and comparing them to the theoretically calculated frequencies we can ascertain whether the two distributions came from the same or different populations. Only if the differences between the two distributions are too large to be attributed to chance can the investigator state that the populations or regions from which the samples were drawn also differ. Whether or not a given difference is significant depends on the conditions of the test as well as on the amount of the difference.

Regional Soil Differences

Field data on soils were collected for each of the regions[5] from survey maps of the U.S. Soil Conservation Service, originally made on air photos at a scale of 4 inches equals 1 mile.

[5]The tidal marsh region was omitted from the statistical analysis.

TABLE 1. — REGIONAL SOIL SURVEYS OF SALEM COUNTY

Region	Total area,[1] acres	Area mapped	
		Acres	Percent
I. Inner Lowland	97,997	27,479	28.0
A	40,890	8,508	20.8
B	46,381	14,492	31.2
C	10,726	4,479	41.8
II. Cuesta	34,682	13,434	38.7
A	15,565	9,068	58.3
B	19,117	4,366	22.8
III. Backslope	70,483	23,977	34.0
A	39,514	16,086	40.8
B	20,262	4,337	21.4
C	10,707	3,554	33.2
County upland total (tidal marsh excluded)	203,162	64,890	31.9

[1]Planimetered from county map.

About 30 percent of the area of the county had been covered by the soil survey, and the survey was sufficiently widespread for statistical analysis. Table 1 gives the area mapped for each region.

The soil types were correlated in terms of surface texture, drainage condition, and profile permeability. These are the important soil–land use determinants in the rural economy of Salem County. Three textural groupings were used: lighter than sandy loam, sandy loam, heavier than sandy loam. Three drainage states were recognized: excessive, well and imperfect, poor and very poor. Four profile conditions were classified: open, moderately compact, compact, cemented.

The soil properties studied are readily mappable in the field. Through their influence on structure, porosity, evaporation, infiltration, and percolation they are important factors in plant–soil moisture relations. The existence of a relationship between the regions previously established according to landform and geologic properties and the areal distribution of the above soil characteristics is to be expected in view of the impact of geologic material on soil formation.

Acreage data on the correlated soil types were collected from each region. Because the texture, drainage, and profile properties of the soils affect land use when acting in combination with each other and not as single isolated factors, the data had to be organized into nonoverlapping classes for use in the chi square

TABLE 2. — FAVORABLE AND UNFAVORABLE SOIL PROPERTIES

Classification	Texture	Drainage	Profile
Favorable	1. Sandy loam 2. Heavier than sandy loam	1. Well drained or imperfectly drained	1. Compact 2. Moderately compact 3. Cemented substratum below 24 inches from surface
Unfavorable	1. Lighter than sandy loam	1. Excessively drained 2. Poorly drained or very poorly drained	1. Open 2. Cemented substratum within 24 inches of surface

contingency table. This was accomplished by organizing the regional acreage data into eight mutually exclusive categories. The various soil properties were classified as favorable or unfavorable for use in the rural economy of Salem County. Two conditions—favorable and unfavorable—for three items—texture, drainage, and profile—yield eight combinations. Table 2 indicates the favorable and unfavorable aspects of the various soil properties.

Of the eight possible combinations of favorable and unfavorable texture, drainage, and permeability conditions, five were found in the field. In order to simplify the manipulation of the data in the contingency table, these five categories were combined into two broad groups of soils based upon the severity of the restrictions which their texture, drainage, and profile permeability properties place upon land use in the county. The five mutually exclusive land classes found in the field are given below:

Group A. Favorable for tillage agriculture.

1. Land with favorable texture, drainage, and profile.
2. Land with favorable drainage and profile, and unfavorable texture, but which is widely cultivated in this particular combination of properties.
3. Land with favorable texture and profile, and unfavorable drainage, but which is also widely cultivated in this particular combination of properties after tiling or ditching.

Group B. Unfavorable for tillage agriculture.

4. Land with favorable drainage, and unfavorable texture and profile.
5. Land with unfavorable texture, drainage, and profile.

The land sites under Group A describe soil conditions which are tilled in the present rural economy. Group B sites are those which suffer from soil handicaps so severe as to make it generally uneconomic to farm them. In some instances their use is limited to specialty crops.

The acreage data observed by regions in the field on these two favorable and unfavorable combinations of soil properties are given in Table 3. These data are the basic raw material used in the chi square analysis. They were assembled from the regions after the boundaries had been drawn and are independent of the method of separating the regions.

The hypothesis of no relationship between the over-all regional pattern and the distribution of the soil data was submitted to a chi square test. The results of the test on the eight physical regions were highly significant. It may be concluded that the regionalization of the county yields an array of the tested sample data whose chi square values are too large to be attributed to chance.

The chi square value obtained in the overall test on the eight regions together means that the regions differ significantly among themselves in their soil properties. It is a

TABLE 3. — OBSERVED REGIONAL DISTRIBUTION OF FAVORABLE AND UNFAVORABLE SOILS (IN ACRES)

Region	Favorable soils	Unfavorable soils	Total
Inner Lowland	25,345	2,134	27,479
A	7,012	1,496	8,508
B	13,936	556	14,492
C	4,397	82	4,479
Cuesta	7,229	6,205	13,434
A	3,263	5,805	9,068
B	3,966	400	4,366
Backslope	20,130	3,847	23,977
A	15,545	541	16,086
B	3,970	367	4,337
C	615	2,939	3,554
County upland total	52,704	12,186	64,890

TABLE 4. – DISTRIBUTION OF SIGNIFICANT DIFFERENCES IN SOIL PROPERTIES BETWEEN PAIRS OF PHYSICAL REGIONS
P = .001

Region	(2) IB	(3) IC	(4) IIA	(5) IIB	(6) IIIA	(7) IIIB	(8) IIIC
(1) IA	Y	Y	Y	Y	Y	Y	Y
(2) IB		Y	Y	Y	N	Y	Y
(3) IC			Y	Y	Y	Y	Y
(4) IIA				Y	Y	Y	Y
(5) IIB					Y	N	Y
(6) IIIA						Y	Y
(7) IIIB							Y

Y = significant difference.
N = no significant difference.

measure of total association. However, it does not necessarily mean that each region differs significantly from every other region. But a system of regionalization must avoid separating out areas which do not differ from each other. In order to guard against this possibility which would nullify the aims of regional analysis, the areas must be tested against each other for significance of difference.

Using the observed data of Table 3 organized into contingency tables for the 28 possible pairs of regions, each region was tested against every other region. The results are given in Table 4. Two separate pairs of areas, IB and IIIA, and IIB and IIIB, originally designated distinct regions, exhibited no significant differences in the tested soil properties. The chi square values of their tests are not large enough to indicate a relation between the boundaries and the observed properties which could not have been due to chance. The samples may have come from the same universe. The observed sample differences for each of these pairs of regions are differences which can be expected to occur by chance alone if the samples came from the same population. Hence the null hypothesis is accepted.

The two pairs of regions which did not differ significantly from each other in soil properties lie in different geomorphic divisions and are underlain by different geologic strata. Nonetheless, the use of geomorphic-geologic criteria resulted in the separation of areas which contain soils whose properties for land use in the county are similar enough to be regarded as homogeneous. Hence the original eight regions can now be reduced to six.

The result of the over-all statistical test on the eight original regions together means that the boundary lines establish areas which differ significantly in soil properties. However, because of the limitations of the over-all test, it is possible that individual pairs of regions may not differ significantly from each other. This is likely to occur when general earth features are used as boundary lines in large-scale studies. Homogeneous pairs of areas can be detected by further statistical tests and their separation avoided.

The use of statistical testing procedures on properly organized data offers a means for objectively establishing and validating geographic regions. Areas can be delimited and submitted to a battery of tests using a variety of data in order to demonstrate the character of regional differences. As both physical and cultural information can be used, the method is applicable to a wide variety of problems in regional geography.

Regional Differences in Land Use, Type of Farm, and Population Groups

In this section a procedure is presented for evaluating statistically the hypothesis of a relationship between the regional pattern and the distribution of selected socioeconomic properties among the several regions. The data used for testing were land use, type of farm, and population group. The validity of using physical regions to assemble these cultural data must be established. This may be accomplished by answering the question: Are the differences in land use, type of farm, and population group observed in the field among the regions large enough to be significant? If they are not, the observed differences may have been due to chance. In this event it is proper to conclude that the hypothesis of relationship is invalid. The chi square test was used in all the analyses.

Land Use. Land use is perhaps the most basic aspect of rural society, for it is the foundation of the agricultural economy. As the limitations of the physical site often find direct expression in land use, it is the key to an understanding of the geographic adjustment to agricultural resources.

Acreage data on three categories of land use were assembled for the eight previously established physical regions by outlining crop

TABLE 5. – OBSERVED REGIONAL LAND USE DISTRIBUTION (IN ACRES)

Region	General field crops	Vegetable crops	Woodland	Total
I. Inner Lowland	11,364	6,825	4,706	22,895
A	2,075	3,523	1,974	7,572
B	6,915	2,797	2,012	11,724
C	2,374	505	720	3,599
II. Cuesta	2,862	450	8,521	11,833
A	560	112	7,856	8,528
B	2,302	338	665	3,305
III. Backslope	10,020	3,703	6,714	20,437
A	8,434	3,103	2,423	13,971
B	1,300	417	2,427	4,153
C	277	183	1,853	2,313
Total	24,246	10,978	19,941	55,165

TABLE 6. – DISTRIBUTION OF SIGNIFICANT DIFFERENCES BETWEEN PAIRS OF LAND USE REGIONS P = .001

Region	(2) IB	(3) IC	(4) IIA	(5) IIB	(6) IIIA	(7) IIIB	(8) IIIC
(1) IA	Y	Y	Y	Y	Y	Y	Y
(2) IB		Y	Y	Y	N	Y	Y
(3) IC			Y	Y	Y	Y	Y
(4) IIA				Y	Y	Y	Y
(5) IIB					Y	Y	Y
(6) IIIA						Y	Y
(7) IIIB							Y

Y = significant difference.
N = no significant difference.

fields on air photo maps at a scale of four inches equal one mile.[6] About thirty percent of the county was surveyed in the following land use classes:

1. General field crops—corn, wheat, oats, barley, soybeans, hay
2. Vegetable crops—tomatoes, peppers, asparagus, lima beans, sweet potatoes
3. Woodland

The regional distribution of acreages in each of the land use classes constituted the observed frequencies. Table 5 gives these data. Are the differences among the regions large enough to be significant? The chi square test gave significant results. It may be concluded that the land use differences observed in the field among the eight regions are too great to be ascribed to chance. The use of physical boundaries has resulted in the separation of regions whose land use characteristics differ significantly.

As was noted earlier, it is possible that individual pairs of regions may not differ significantly even though the over-all test on the eight regions was significant. In order to prevent the separation of regions into areas whose land use properties do not differ, each region was tested against every other region for significance of difference in their observed land use properties. The results are summarized in Table 6. Regions IB and IIIA showed no significant differences. This means that the differences in land use between these two areas observed in the field may have been due to chance. Hence the null hypothesis is accepted. The land use acreage samples drawn from IB and IIIA may have come from the same region.

Type of Farm. Type of farm refers to the major kind of agricultural activity of the farm unit. It is closely related to land use, but similar land uses may be associated with different types of farms. Four type-of-farm classes were used in this study: poultry, dairy, vegetable, and rural nonfarm. Classification was made by direct observation of the farm enterprise. Residences in the open country were classified as rural nonfarm. Villages, hamlets, clusters of residences along urban fringe areas, or homes for migratory workers were excluded.

Each residence was classified in the field and located on a county map. The number of units in each category were then assembled by regions according to the previously established physical boundaries. The entire county was covered except that the tidal marsh region was again omitted. The observed regional frequency distributions in the selected types of farms are given in Table 7. These are the basic observed data used in the chi square tests.

Are the differences in the types of farm found in the various regions large enough to be significant or may the observed differences be attributed to chance? The result of the chi square on all the regions together indicates that the differences observed in type of farm among the regions are too large to be attributed to chance. The null hypothesis is rejected and it may be concluded that the regions dif-

[6]The tidal marsh region was omitted.

TABLE 7. – OBSERVED REGIONAL TYPE OF FARM DISTRIBUTIONS (IN NUMBER OF UNITS)

Region	Poultry	Dairy	Vege-table	Rural nonfarm	Total
I. Inner Lowland	5	324	214	392	935
A	1	27	175	144	347
B	3	241	14	212	470
C	1	56	25	36	118
II. Cuesta	1	102	22	227	352
A	1	12	15	102	130
B	–	90	7	125	222
III. Backslope	191	247	90	356	884
A	14	195	22	175	406
B	81	47	35	137	300
C	96	5	33	44	178
Total	197	673	326	975	2,171

fer significantly in their type of farm characteristics.

Because of the nature of the chi square test it is possible to obtain significant results in an over-all test, while pairs of regions may not differ significantly. To prevent the separation of a homogeneous area into two regions, each region was tested against every other region. The results are given in Table 8. Several pairs of regions showed no significant differences in their type of farm distributions. These are regions IB and IIB, IB and IIIA, and IIB and IIIA. It may be concluded that the differences observed in the field between these pairs of regions, real as the sample differences are, may have been due to chance. The type of farm samples used in the chi square test may have been drawn from the same population or region. Homogeneous type of farm regions have been separated into smaller units which do not differ significantly from each other. The chi square analysis of the regional data has detected this error.

TABLE 8. – DISTRIBUTION OF SIGNIFICANT DIFFERENCES BETWEEN PAIRS OF TYPE OF FARM REGIONS P = .001

Region	(2) IB	(3) IC	(4) IIA	(5) IIB	(6) IIIA	(7) IIIB	(8) IIIC
(1) IA	Y	Y	Y	Y	Y	Y	Y
(2) IB		Y	Y	N	N	Y	Y
(3) IC			Y	Y	Y	Y	Y
(4) IIA				Y	Y	Y	Y
(5) IIB					N	Y	Y
(6) IIIA						Y	Y
(7) IIIB							Y

Y = significant difference.
N = no significant difference.

Population Groups. Several population groups live in Salem County and participate in its rural economy. These groups are not uniformly distributed throughout the county but, like type of farm and land use, are concentrated in certain areas, engaging in selected kinds of agricultural activity. The tendency of rural peoples to congregate in certain areas and develop distinctive agricultural patterns has been noted by many investigators.[7]

In rural Salem County four population groups can be recognized. These are:

1. North Europeans—descendants of the early settlers, English, Scotch, Swedes, Dutch, Finns, French, and later immigrants, Irish and Germans.
2. Negroes
3. Jews
4. Italians

This classification covers virtually all the people in the rural areas, except for a scattering of Poles and Slavs, and a few recently settled Japanese. Each rural farm and rural nonfarm homestead was classified. Villages, hamlets, clusters of residences along urban fringe areas, and homes for migratory workers were excluded. The classification was based on a mail box survey of names, supplemented by observation and interviews. Names provide a simple and effective method of classifying people ethnically.[8] Because the survey was made in terms of homesteads the data are recorded as numbers of rural residences, and not as population.

Rural residences were thus classified and located on a county map. The data were then assembled by regions according to the pre-

[7] E. de S. Brunner, *Immigrant Farmers and Their Children* (Doubleday Doran & Co., New York, 1929); L. G. Davis and G. I. Hendrickson, *Soil Type as a Factor in Farm Economy in the Town of Lebanon* (Storrs Agricultural Experiment Station Bulletin 139, 1926); J. S. Gibson, "Land Economy of Warren County, Kentucky," *Economic Geography*, Vol. 10 (1934), pp. 74–98, 268–287; W. M. Kollmorgen, "A Reconnaissance of Some Agricultural Islands in the South," *Economic Geography*, Vol. 18 (1941), pp. 409–430.

[8] P. Meigs, 3rd, "An Ethno-Telephonic Survey of French Louisiana," *Annals*, Association of American Geographers, Vol. 31 (1941), pp. 243–250.

TABLE 9. — OBSERVED REGIONAL POPULATION GROUP DISTRIBUTION
(IN RURAL RESIDENCE UNITS)

Region	Negro	Italian	Jewish	North European	Total
I. Inner Lowland	115	70	11	765	961
A	46	68	4	217	335
B	57	2	6	430	495
C	12	—	1	118	131
II. Cuesta	118	—	—	271	389
A	43	—	—	103	146
B	75	—	—	168	243
III. Backslope	38	25	137	664	864
A	20	2	9	395	426
B	14	15	55	205	289
C	4	8	73	64	149
Total	271	95	148	1,700	2,214

TABLE 10. — DISTRIBUTION OF SIGNIFICANT DIFFERENCES BETWEEN PAIRS OF POPULATION GROUP REGIONS
P = .001

Region	(2) IB	(3) IC	(4) IIA	(5) IIB	(6) IIIA	(7) IIIB	(8) IIIC
(1) IA	Y	Y	Y	Y	Y	Y	Y
(2) IB		N	Y	Y	N	Y	Y
(3) IC			Y	Y	N	Y	Y
(4) IIA				N	Y	Y	Y
(5) IIB					Y	Y	Y
(6) IIIA						Y	Y
(7) IIIB							Y

Y = significant difference.
N = no significant difference.

viously established physical pattern, except that the tidal marsh region was omitted. Of the total rural residences in the county 7.1 percent were not classified. The observed regional frequency distributions of the population groups are given in Table 9. These are the basic observed data used in the chi square analyses.

Again it is necessary to ascertain whether the distribution of the various population groups among the regions is significantly different, or whether the observations may have been due to chance. Following the procedure used earlier an over-all test on the eight regions was run. The results were significant. The spatial organization of the county that has been established by the geomorphic-geologic factors separates regions which differ significantly in their population groups.

As this is a measure of total association, it is necessary to test each region against every other region to see whether all the possible pairs of regions differ significantly from each other. The results of the chi square tests on the 28 pairs of regions are given in Table 10. Several pairs are composed of regions which do not differ significanty from each other in their population groups. These are IB and IC, IB and IIIA, IC and IIIA, IIA and IIB. This means that the members of these regional pairs are homogeneous in the composition of their population groups. The differences observed in the field are differences which may have been due to chance sampling. In effect, the boundary lines which have separated these pairs into regions are misplaced in terms of this criterion of homogeneity, for they have delimited areas which do not differ significantly from each other.[9]

CONTRIBUTION OF STATISTICAL TESTING TO REGIONAL ANALYSIS

Areal Patterns of Cultural Response

The eight regions separated by the geomorphic-geologic boundaries exhibited varying cultural responses in land use, type of farm, and population characteristics. The regions also showed varying degrees of homogeneity with each other for any given socioeconomic feature. Thus, in land use IB and IIIA were homogeneous; in type of farm, IB and IIB, IB and IIIA, and IIB and IIIA were homogeneous; in population group, IB and IC, IB and IIIA, IC and IIIA, and IIA and IIB were homogeneous.

The response pattern is complex but it is possible to organize cultural regions defined by specific traits. This can be accomplished

[9]The more statistically minded reader will note that in the data reported in Tables 7–10 the sample size approached the size of the finite population. The point thus may be made, with considerable justification, that the report is dealing with populations and not samples, and hence probability concepts and significance tests are not applicable. In such a situation it is regarded as acceptable practice by many statisticians to consider the finite population itself as a sample from a larger universe. This problem, which confronts social scientists and experimental scientists, is discussed in *Statistics for Sociologists* by M. J. Hagood and D. O. Price (rev. ed.; Henry Holt & Co., 1952), pp. 284–294.

by combining regions which have exhibited homogeneous responses. Each characteristic may be treated separately, but, as there is not complete agreement on homogeneity for all the properties, a multiplicity of culture regions would result. Regions IB and IIIA, however, are consistently homogeneous in all the tested traits. They form a single region of cultural response. Such a combination, of course, is rational and nonstatistical. All the other regions are regarded as distinct. This is true only if the criterion of regional distinction is a significant difference in all three tested socioeconomic traits. If any single characteristic is used another regional pattern of cultural response emerges.

Interrelations among Regional Traits

If regions are areas homogeneous in terms of specific criteria, they must be distinguished from other regions by a particular kind of internal cohesion. Regions are set apart from each other because each is characterized by a peculiar matrix of areally associated features. Definition of the nature of this association would reveal the fundamental structure of the regional pattern. The use of statistical tools for studying relationships is applicable to this problem.

The various soil and socioeconomic traits have been studied separately and individually region by region. The statistically significant differences among the regions in these traits have been used to validate the boundary lines. However, the existence of a relationship among the properties themselves has not been established. These interrelationships are responsible for regional quality. To answer the question whether for the county as a whole there is a significant association among the characteristics studied, chi square was used.

The association between soil texture, drainage, and profile permeability and the use of land for general field crops, vegetables, and forests was investigated. In the present study this is a basic problem because the organization of the regional pattern was based on the assumption of such a relationship. The impact of soils on land use has been the link through which natural forces have exerted their influence on the local agricultural economy.

Chi square tests were run separately on the relationship between soil texture and land use, soil drainage and land use, and soil profile permeability and land use. The observed acreages in each of the land use classes distributed among the soil properties are given in Table 11. The results of the chi square tests were highly significant.

TABLE 11. — OBSERVED LAND USE IN SOIL PROPERTY CLASSES (IN ACRES)

Soil property	Land use			
	General field crops	Woodland	Vegetables	Total
Texture				
Lighter than sandy loam	2,069	8,903	2,887	13,049
Sandy loam	8,684	5,496	3,176	17,356
Heavier than sandy loam	13,493	6,352	4,915	24,760
Total	24,246	19,941	10,978	55,165
Drainage				
Excessive	71	2,801	36	2,908
Well and imperfect	20,887	8,148	10,174	39,209
Poor and very poor	3,288	8,992	768	13,048
Total	24,246	19,941	10,978	55,165
Profile				
Open	1,380	7,541	2,031	10,952
Moderately compact	15,514	8,572	6,663	30,749
Compact	5,721	2,511	1,673	9,905
Cemented	1,631	1,317	611	3,559
Total	24,246	19,941	10,978	55,165

TABLE 12. — OBSERVED TYPES OF FARM BY POPULATION GROUPS (IN NUMBER OF UNITS)

Population group	Poultry	Dairy	Vege-table	Rural nonfarm	Total
Negro	1	3	10	249	263
Italian	4	3	68	18	93
Jewish	111	10	7	16	144
North European	48	652	209	616	1,525
Total	164	668	294	899	2,025

The land use properties of the soils have been strongly influenced by the geologic strata from which they have been derived. As it is the differential erosion of these strata which also has been responsible for the geomorphic pattern, the use of geologic-geomorphic boundaries to divide the county into regions of cultural response has been validated statistically.

Another important social interrelation is that between population group and type of farm or rural nonfarm. The observed type-of-farm-distributions classified by population groups are given in Table 12. The results of the chi square tests indicate a significant relation between population group and type of farm. The various population groups resident in the county show preferences for each of the several agricultural opportunities. A region with a high percentage of a certain population group will show a correspondingly large number of its farms in the type for which this group reveals a preference.

Interrelations among and between physical and socioeconomic traits of regions are responsible for the specific character which areas possess. Regional quality stems from a matrix of interrelated traits. These are often indicated by superficial observation, but there is no way of knowing if the observations may have been due to chance unless statistical tests of significance are employed.

The procedures used in this study enable the investigator to pinpoint the relationship between the natural environment and human activity that is responsible for the distinctive character of regions. Since not all phases of the natural environment have an equal impact on human activity only the most pertinent physical agents affecting areal response patterns should be used in studying relationships.

Certain aspects of the soil profile were regarded as the economically critical land-use determinants. These were surface texture, drainage condition, and profile permeability. Two originally delimited areas did not differ significantly in certain combinations of these properties. Hence they are parts of a single region. In later studies of the cultural properties of the same two areas, they also did not differ significantly in land use, type of farm, and population group. The differences observed in the field which could lead one to conclude erroneously that the two areas were different (and hence were regions), have been shown to be differences which might have been due to chance. All the other originally delimited areas exhibited significant differences in their soil properties and one or more of the cultural traits. For these areas the differences observed in the field may have been shown to be too large to be attributed to chance.

On the evidence presented by this method of analysis it is safe to conclude that the geomorphic-geologic criteria had erred in separating a homogeneous geographic region into two parts. The analysis indicates that there is a common relationship between the natural environment and the cultural response in each part and that they comprise a single region. As all the other regions exhibited significant differences in the tested soil or socioeconomic characteristics, the relation between the natural environment and the patterns of human activity would appear to be distinctive for each.

Definition of the Level of Regional Differences

The definition of boundary lines is basic to regional differentiation. A review of the procedures employed by geographers in regional analysis indicates that one fundamental methodological assumption remains unchallenged.[10] This assumption has to do with the amount of difference between areas. What is the basis for using a given level of difference between areas to decide whether they are regions? How large a difference between areas must a boundary line produce before it is accepted?

[10] P. E. James and C. F. Jones, *op. cit.* See chapts. 2 and 10 for extensive bibliography.

When climatic, landform, or soil boundaries are used to divide an area into regions how different must the individual areas be in land use, type of farm, level of income, occupational structure, etc., in order to justify the separation?

In each case the amount of difference regarded adequate to accept a boundary line is defined subjectively by the investigator, whether or not differences are apparent from an inspection of the data. Statistical analysis provides a method for objectively stating the level of difference between areas which must be satisfied to set up regions. In statistical terminology differences are significant when the probability of their being due to chance is less than the investigator is willing to accept. The data which are used to compare separate areas constitute samples from the same or different populations. If the differences between the samples are not large enough the samples may have come from the same population. The sample differences observed in the field may have been due to chance. Hence the areas do not differ significantly and they should not be separated.

The use of statistical testing procedures on properly organized data thus detects the possibility of subdividing regions into parts which do not differ significantly by referring to an objectively established level of difference. This level of difference must be satisfied. It is the basis of regional delimitation. In this way statistically validated regions, which differ from each other in selected physical or cultural properties, can be separated. Delimited areas can be submitted to a battery of tests. Those parts which show significant differences are retained as regions; those which do not can be combined to form new areal divisions.

A final note of caution on the interpretation of statistical tests should be added. The hypotheses tested are valid only statistically. Other hypotheses could have been tested as well, and these also might have been valid statistically. It is for the investigator to decide, in the light of geographic concepts and the organization of the study, which statistical hypothesis he is willing to accept because it provides insight into the nature of regional relationships.

NEW FORMAT OF THE ANNALS

This issue of the *Annals* introduces a new format. The change in format was adopted after considerable discussion by the present and previous Publication Committees, the Council, and the Editor. The new page design and type face will accommodate about one-third more printed material per page, but will still provide a readable type size. The new paper suitable for both text and figures will simplify layout problems and reduce the problem of the use of illustrations. The Editor hopes that the new format will meet the approval of readers.

WALTER M. KOLLMORGEN
Editor

RODERICK PEATTIE, 1891–1955

RODERICK PEATTIE, GEOGRAPHER AND ROMANTICIST, 1891–1955

GUY-HAROLD SMITH

The Ohio State University

ON the outskirts of Omaha, in the heat of summer, Roderick Peattie was born on August 1, 1891. His parents were Robert Burns Peattie and Elia Wilkinson Peattie, both to become distinguished in the field of writing. His brother Donald Culross Peattie is a well-known and distinguished author also. When he was a small boy, his family moved to Chicago where he grew up in an urban environment. This made it possible for him to attend the University of Chicago from which he received the S.B. degree in 1914. He then went on to Harvard University for graduate work in geography, and was awarded the Ph.D. degree in 1920.

He began his teaching service as an assistant in physiography at the University of Chicago. He taught also at Radcliffe College and at Harvard University while continuing his work for the doctorate. His first regular teaching position was at Williams College in 1919-20. He then came to The Ohio State University, first as an Assistant Professor in the Department of Geology. In 1924, he was transferred to the Department of Geography where he taught for more than thirty years, except for two years which he spent abroad. In 1927-28 he was in Europe working on his *Mountain Geography* and in 1944-45 he was with the Office of War Information in the Union of South Africa.

Professor Peattie was married to Margaret Rhodes of Chicago in 1917. Their children include Roderick Elia Peattie, Mrs. Ann Woods, and Michael Ransome Peattie. Margaret died in October, 1946. A year later he married Ruth Cavett, who survives him.

He served in France in World War I and held other positions briefly, but he was fundamentally a teacher and an author. His contributions to the literature of geography were numerous. His bibliography includes more than sixty items, including ten books.

In the spring and summer of 1954, he and Mrs. Peattie were on an extended trip to west and central Africa. Upon his return, he worked hard to complete a manuscript on Africa south of the Sahara. This work was substantially complete at the end of the school year when he went to his summer place near Wallingford, Vermont, where he became ill shortly after his arrival. He was taken to a hospital in Rutland where he died quietly on the evening of June 18, 1955. He was sixty-three years of age. The remains were cremated, and the ashes scattered on a mountain top near his Vermont home. Because of his expressed wish, no formal funeral services were held. Later, on November 13, 1955, brief memorial services were held in St. Stephen's Episcopal Church near the campus of The Ohio State University. In his autobiography he wrote, "When you bury me, my friend, do not have stately mourning. Have no stranger pronounce platitudes over my body. Rather let some close friend read a grand and stirring thing such as I, in life, should have liked. Select some poem of adventure. Tell some tale of man's search for happiness . . . I shall have had my full drink of life." His wishes were respected.

It is too soon to appraise his work with objectivity. It may be enough to say here that the Department of Geography and The Ohio State University have lost a devoted and distinguished member of the faculty. The loss of the prestige and distinction he brought to us is keenly felt.

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Emery Troxel. *Economics of Transport.* New York: Rinehart. 1955. 837 pages, index. $7.50.

Russell E. Westmeyer. *Economics of Transportation.* New York: Prentice-Hall. 1952. 741 pages, index, maps. $6.50.

The recent publication of a number of textbooks dealing with the principles of transportation is of interest to geographers in at least three major respects: (1) the possible enrichment of geographic studies by a better understanding of such substantive transportation features as rates and regulation; (2) the distinctions which can be noted between the geographer's and the transportation economist's approach to transportation; (3) the possible geographic significance of some of the conceptual material contained in the texts.

Transportation rates and regulation both have been neglected generally in geographic studies despite their strong regional implications. Geographers may note situational advantages at certain centers, for instance, which may or may not find actual expression in rates. Toledo's apparent distance advantage over Chicago for overseas shipping is negated by freight rates; widespread rate blanketing from the Pacific Coast distorts distance relationships almost beyond recognition; and similar rate irregularities are perceptible in the trade pattern of virtually any locality. In considering regional development, the impact of freight rates might be compared to the impact of zoning on urban development or of exchange controls on international trade. Cases in point are the effects of changing rate ratios on the distributional shifts in such industries as flour-milling, meat-packing, and aluminum-refining. Thus, additional insights into the geographic study of small regions might well follow from an investigaton of key freight rates and a better understanding of rates in general. It would also seem that a familiarity with the web of regulations which constitute the heritage of present-day transport companies would be helpful in analyzing the vital role of transportation in areal organization. There is clear geographic import in such regulatory features as the techniques of airline route certification, the importance of regulatory exemptions for bulk waterway carriers and private motor carriers, and the possible effects of changing government transportation policy upon existing patterns.

For the geographer interested in expanding his knowledge of transportation, Daggett is the most useful of the six major transportation texts published since the war because of his emphasis on commodity flow and his liberal utilization of maps. The focus of this review will therefore be on Daggett, with frequent reference to the other texts so as to illustrate their advantages for particular purposes.

Typically, these introductory transportation books consist of a few brief chapters on the history and characteristics of the different forms of transportation and an extended discussion of the development of regulation and the theory and practice of freight rates. Locklin and Bigham and Roberts are fairly representative of this pattern. Westmeyer is distinguished by his separate consideration of each form of transportation and his greater emphasis on highway, water, and air transportation. Daggett and Fair and Williams lay more stress on maps and commodity movement than do the others, although Daggett also emphasizes traffic management features. Troxel departs most markedly from the typical in his attempt to apply marginal analysis techniques to the allocation of transport resources. Apart from Troxel, however, these texts provide little help to the geographer who hopes to enhance his grasp of the versatile tool of economic analysis by noting its application to the spatial phenomena of transportation. Although it is difficult for a non-economist to evaluate economic content, it does seem that most of the books provide fundamentally descriptive treatments of transportation as an institution, the functions and limitations of which are delineated primarily by a legal-political rather than an economic environment.

A particularly useful feature of Daggett is his concentration of geographic material in the earlier chapters. The first eleven chapters consist of: (1) a few brief and general introductory chapters; (2) a chapter on each of the major forms of transportation including some standard maps, regional groupings of railroads, and discussions of commodity flow on the inland waterways; and (3) a section on transportation geography which includes extended discussion of the Great Lakes, land transport routes, and rail commodity flow. References to rate and regulatory features are scattered through this section, particularly in those chapters dealing with commodity flow. The remaining 24 chapters deal at some length with rates and regulation, with separate discussions of such topics as competition and the relations of carriers with each other in such matters as car interchange, terminals, and coordination. This more detailed and legalistic material is rendered considerably more meaningful to the geographer, however, by the context of maps and commodity flow in which it was first encountered.

Daggett's treatment of rates includes the impor-

tance of constant costs in transport, problems associated with mileage scales and commodity classification, the importance of the various types of competition in setting rates, group and basing point rates, local discrimination, and the long and short haul clause. Cohesion is perhaps the strongest feature. He relates the freight-rate structure to the commodity flows previously discussed, to those aspects of regulation most closely linked to rates, and to his selective discussion of location theory. His treatment of mileage scales is notable for its clarity and for the effective use of brief illustrative tables to demonstrate quantitatively the importance of terminal costs and line-haul costs in the establishment of a rate structure.

The mechanics of ascertaining freight rates, of course, does not fall within the scope of any of the introductory transportation books, all of which stress the broader bases of freight rates. For a more specific coverage of the documentary maze attendant upon freight-rate determination it is necessary to turn to textbooks in the field of traffic management, such as Thurman W. Van Metre, *Industrial Traffic Management* (McGraw-Hill, 1953, $6.50); Charles A. Taff, *Traffic Management, Principles and Practice* (Irwin, 1955, $6.00); and Newton Morton and Frank V. Mossman, *Industrial Traffic Management* (Ronald, 1954, $6.50). These books provide useful guides although all are inevitably detailed and legalistic in tone. Taff is more condensed and more nearly readable than others of the *genre*; Van Metre is widely used and is quite thorough; Morton and Mossman contains a relatively clear step-by-step description of the mechanics of looking up rates. Still, the geographer would find himself considerably short of the goal of actually looking up rates himself with any degree of confidence. The inconsistencies and exceptions, the widespread use of multiple footnotes, and the remarkably circuitous phraseology render this task a time-consuming and uncertain one. He can, however, develop sufficient awareness of these complexities to facilitate the discovery of freight rate peculiarities and groupings of local significance through intelligent interview of farmers, traffic managers, and transportation agents.

Daggett's treatment of regulation suffers from an overabundance of detail both in text and in extended footnotes. Although few pertinent regulatory features are omitted, there is no evidence of a hierarchy of significance to aid the geographer in evaluating key features and their regional impact. Some of the other books are more useful than Daggett in this respect since their more condensed chapters on regulation necessarily highlight important features. Westmeyer's strong organizational emphasis on the different forms of transportation is particularly effective in view of the regulatory differences between rail, highway, water, and air transportation. Each chapter dealing with the regulatory characteristics of a particular form of transportation is followed by two chapters on the problems and policies of that form, most of which are closely linked to regulation. Westmeyer's treatment is detailed and therefore has the advantage of presenting transport regulation in a problem-oriented context. In dealing with forms of transportation other than rail, geographers may go beyond Westmeyer to such separate textbooks as Charles A. Taff, *Commercial Motor Transportation* (Irwin, 1950, $5.00); Joseph L. Nicholson, *Air Transportation Management* (Wiley, 1951, $6.00); and Carl E. McDowell and Helen M. Gibbs, *Ocean Transportation* (McGraw-Hill, 1954, $7.00), a book containing sections on ports, world trade, and trade routes.

Aside from rates and regulation, there are certain special advantages of some of these books to geographers. Daggett's section on terminals, for instance, is of considerable interest to an urban geographer, and it may serve as an introduction to the elaborate treatment of this subject in the traffic management books. A unique feature of Fair and Williams is a section which treats transport according to function. Thus, the competitive merits of each form are separately evaluated for passenger service, merchandise service, and bulk freight service. Locklin, probably the most widely used text, provides a clear and comprehensive treatment, with the traditional emphasis on rail transportation. Troxel provides an interesting analytical approach, but it is difficult for a geographer to fully grasp the implications of a book which sometimes treats transportation chiefly as a vehicle for the illustration of economic theory.[1] However, even the first four chapters are rich in simple but provocative new interpretations of familiar transport phenomena.

Over and above the substantive material contained in these books, there is considerable interest for the geographer in noting certain distinctions between his own approach to transportation and that of such distribution-minded institutional economists as Daggett, even though there are, of course, probably as many specific geographic approaches to the study of transport as there are transport geographers. One obvious distinction is the absence of world coverage in the transportation texts. Geographers are acutely conscious of the additional insights into the nature of transportation to be gained from observing its development within an entirely different institutional context as, for instance, in the Soviet Union, or in the underdeveloped countries where the cultural and economic significance of the more primitive forms of transport is great. For a survey of foreign transport, one must turn to W. S. Woytinsky and E. S. Woytinsky, *World Commerce and Governments* (Twentieth Century Fund, 1955, $10.00), or to the brief chapters on transportation in a variety of economic geographies. The Woytinsky compendium includes interesting chapters on the different forms of transportation and broad international comparisons of transportation characteristics based on selected national statistics, a surprising number of which are prewar. Among the geography texts, *Industrial and Commercial Geography* (third edition: Holt, 1946), by J. Russell Smith and M. Ogden Phillips, still contains the most stimulating discussion of transportation from a world regional point of view. The 1955 edition

[1]Review by Charles Landon, *American Economic Review*, Vol. XLVI (June 1956), p. 489.

of this book is something of a disappointment to the transportation geographer in that the intensification of the topical aspects of the organization has resulted in the condensation and loss of regional flavor in the transportation section. An encyclopedic coverage of route maps and recent statistics on the world's railroads and airlines is contained in such publications as *World Railways* (Rand McNally, $25.00) and *World Airline Record* (Roy R. Roadcap and Associates; 327 S. La Salle St., Chicago, $17.50).

More fundamental distinctions between the approach to transportation found in these texts and that of a geographer lie in the economist's lack of regional consciousness and in his generally ineffectual use of maps. The lack of recognition of the interrelation between transportation and its region in all but a few instances, such as Fair and Williams' discussion of the southern basing point system, is to be expected in works emphasizing the study of transportation as a systematic specialty. In addition, however, there is an important difference between geographer and transportation economist in the latter's tendency to regard maps as being primarily of illustrative rather than analytical value. This is evident from the consistent lack of coordination between map and accompanying text. With the exception of a few small maps of early canals in Locklin, the maps are seldom drawn to fit the objectives of a particular discussion. The same standard government agency or transportation association maps depicting the U. S. rail network, C. A. B. routes, navigable waterways, etc., are used in most of the texts. Even in Daggett's Great Lakes discussion, perhaps the most geographical section in any of these books, the lack of coordination between map and text is marked. Daggett's discussion emphasizes the postwar commodity flow pattern; his maps show the 1935 flow. No attempt is made to make the prewar maps a useful adjunct to clear visualization of the postwar pattern by pointing out similarities and differences between the two. Instead, places and commodity flows are introduced which do not appear on the 1935 maps, and a number of 1935 flows with no postwar counterpart are left unexplained.

Another deficiency in the use of maps is to be found in Daggett's section on rates and commodity flow, where he accepts uncritically maps of origin groups devised by government agencies for administrative or specific rate-making purposes. This, together with the lack of any but the most broadly generalized commodity flow maps, weakens Daggett's treatment of the subject, despite an impressive fund of knowledge. This weakness also underlines the magnitude of Ullman's contribution to transportation geography in his series of state-to-state commodity flow maps compiled from railway waybill statistics. Had Daggett been able to draw on these maps or on geographic studies integrating flow data with static features such as meaningfully delimited producing areas, the commodity flow section would have been much stronger.

In Daggett and in Fair and Williams, some of the small rate maps and accompanying discussions are fairly well coordinated and do represent a more analytical use of maps, although their geographic relevance is greatly reduced by the necessarily selective coverage. The spatial complexity of such items as the Lake Cargo Coal Rate case and the various transcontinental cases leads naturally to a greater reliance on maps in the text discussion. Many of these maps were taken from Stuart Daggett and John P. Carter, *The Structure of Transcontinental Freight Rates* (University of California Press, 1947, $4.00), probably the finest example of effective map use among non-geographic works on transportation.

Possibilities for map representation of transport phenomena other than existing routes and commodity flow go unrecognized in all texts. Troxel, however, does give considerable textual emphasis to the importance of spatial limits of services and schedules in the allocation of transport resources. This at least indicates an awareness that map analysis could be useful over a wide range of transport problems. In the transport development of underdeveloped areas, for instance, the use of geographic techniques need not terminate with the construction of a new route or the determination of a basic commodity flow but could prove helpful in a continuing chain of decisions as to the most strategic route placement of such items as coach fares, centralized traffic control, heavy rail, single-unit diesel cars, and added inter- and intra-agency competition.

Finally, mention should be made of such conceptual material as Troxel's spatially oriented economics and the location theory sections of the other texts. For instance, Troxel's ideas of evaluating route extensions or improvements by application of the economist's analysis of marginal-cost, marginal-revenue equilibrium might ultimately be applied to map studies. Testimony to the growing significance of location theory in transportation as well as in geography is given by the fact that each of these texts contains a location theory section. In a brief but clear presentation, Daggett stresses those aspects of location theory which seem to be most closely linked to his preceding treatment of freight rates, thereby lending a more empirical tone to the discussion than is customarily the case. Neither Daggett nor any of the other economists, however, make any serious attempt to integrate the more complex concepts of Lösch and Isard into their surveys. Also, Daggett criticizes certain aspects of location theory on the oft-cited grounds that they fail to correspond to observed realities since so many complexities and inconsistencies have been assumed away.

To the extent that location theories are intelligible to the geographer, however, and do not tend to bias field techniques, it seems to this reviewer that they are of considerable value as tools which facilitate description, despite their failure to describe adequately the complexities of a given distribution. Few of the individual theories aspire to a holistic explanation of the spatial expression of economic phenomena. Rather, they attempt to identify spatial reactions to selected sets of stimuli which have been limited specifically by initial assumptions. Thus, even such early and oversimplified models as Von Thünen's rings or Burgess' concentric zones are not rendered invalid merely because axes of major transport activity

distort the regular circular patterns they posited. If the theories had merit in the first place, spatial reactions could still follow the postulated sequence; they merely would be arranged relative to a set of linear rather than punctiform stimuli.

Moreover, an even greater discrepancy between reality and a given model due to the presence of important residual variables may not necessarily strip it of geographic research utility. For example, the gravity model has enough descriptive validity to facilitate the detection of additional variables when applied to certain transportation distributions, and to aid in the formulation of further quantitative or qualitative postulates concerning them. The systematization of conspicuous similarities between areas, in turn, helps isolate less obvious unique features which serve to differentiate particular areas. Thus, the regional geographer's appreciation of the unique may be heightened and rendered more precise by the theoretical studies of distance made by location theorists, spatially-oriented economists, and systematic geographers.

Which of the provocative ideas emerging from such studies will be valuable and which will prove to be mere exercises in spatial metaphysics is difficult to determine. Judgment must await the repeated application of new concepts and models to the geographer's painstaking, empirical investigations of transportation and other phenomena within a variety of settings and on a variety of scales.

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APPENDIX

1. Carl E. McDowell and Helen M. Gibbs. *Ocean Transportation*. New York: McGraw-Hill, 1951. 675 pages, index, maps. $7.00.
2. Newton Morton and Frank V. Mossman. *Industrial Traffic Management*. New York: Ronald, 1954. 538 pages, index. $6.50.
3. Joseph L. Nicholson. *Air Transportation Management*. New York: Wiley, 1951. 446 pages, index, maps. $6.00.
4. Henry Sampson, editor. *World Railways*. Chicago: Rand McNally. 550 pages, maps. $25.00.
5. J. Russell Smith and M. Ogden Phillips. *Industrial and Commercial Geography*. New York: Holt, third edition, 1946. 978 pages, index, maps.
6. Charles A. Taff. *Commercial Motor Transportation*. New York: Irwin, 1950. 446 pages, index, maps. $5.00.
7. Charles A. Taff. *Traffic Management, Principles and Practice*. New York: Irwin, 1955. 570 pages, index. $6.00.
8. Thurman W. Van Metre. *Industrial Traffic Management*. New York: McGraw-Hill, 1953. 552 pages, index. $6.50.
9. *World Airline Record*. Chicago: Roy R. Roadcap and Associates, 327 S. La Salle St. 500 pages, index, maps. $17.50 ($10.00 for libraries).
10. W. S. Woytinsky and E. S. Woytinsky. *World Commerce and Governments*. New York: Twentieth Century Fund, 1955. 907 pages, index, maps. $10.00.